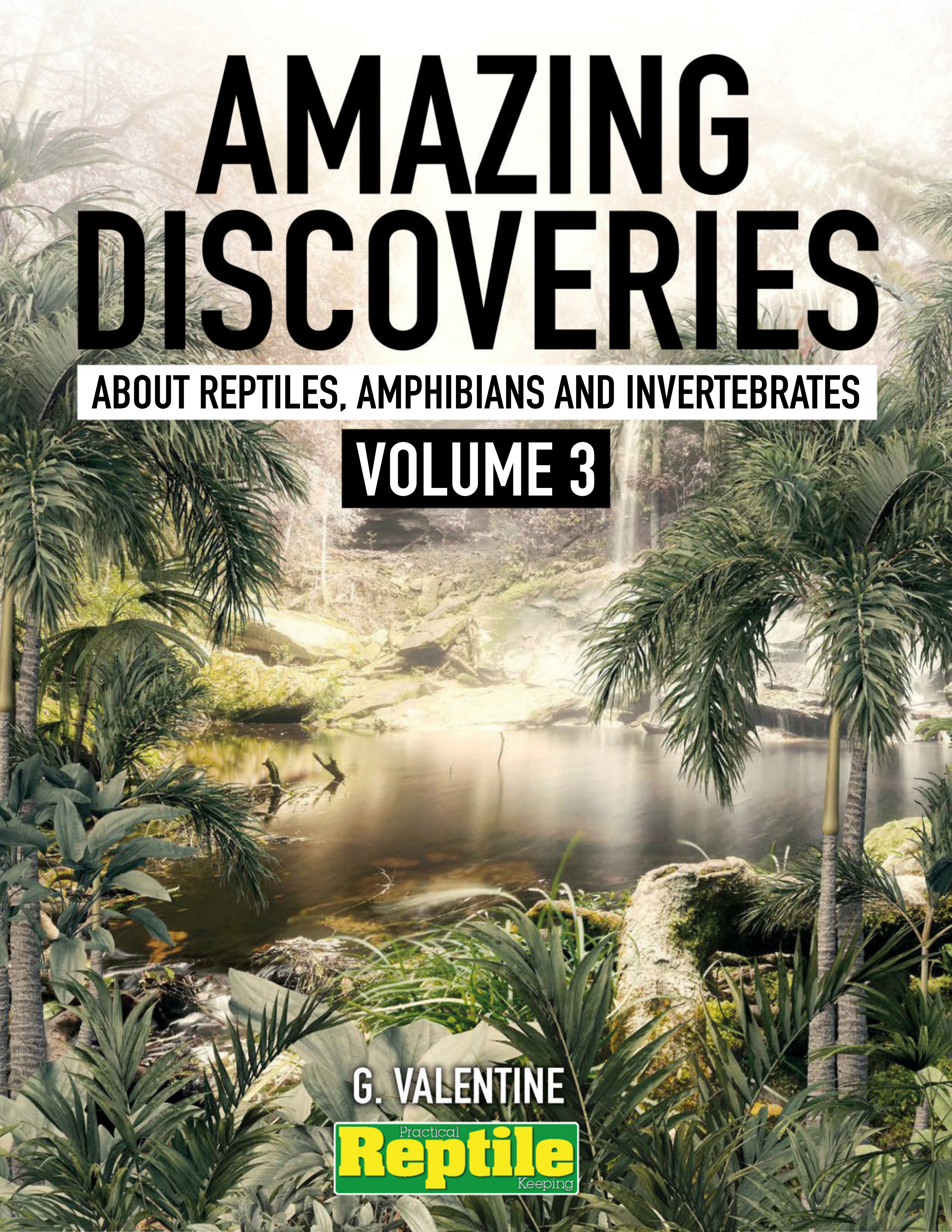
AMAZING DISCOVERIES

ABOUT REPTILES, AMPHIBIANS AND INVERTEBRATES

VOLUME 3



G. VALENTINE

Practical Reptile Keeping

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AMAZING DISCOVERIES

ABOUT REPTILES, AMPHIBIANS AND INVERTEBRATES

VOLUME 3

It is often overlooked how fast our knowledge about reptiles, amphibians and invertebrates continues to grow, revealing not just the existence of new species, but also amazing insights into the lifestyles and biology of these groups. Here are some more of the most recent remarkable findings in this field. Don't miss G.Valentine's News and Views round-up that appears every month in the magazine, if you are keen to read the very latest information. Also, the first two volumes of this series are available online at <https://pocketmags.com/practical-reptile-keeping-magazine>

David Alderton

David Alderton,
Editor, *Practical Reptile Keeping*
practicalreptilekeeping@gmail.com

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Publisher and editor: David Alderton
Email: practicalreptilekeeping@gmail.com
Art Editor: Rob Terry
Email: rob@focusedondesign.co.uk

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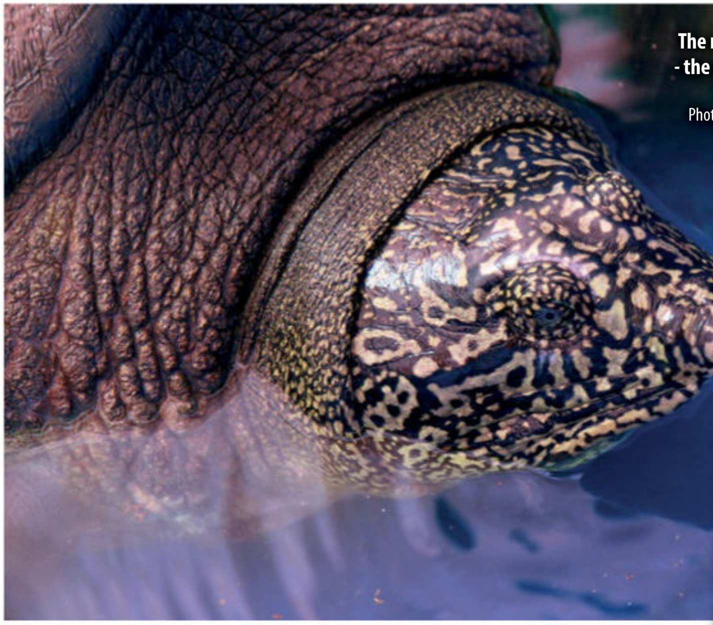
Contents

4 New hope for previously doomed turtle species
7 Why crocs have not changed a lot
8 The strange discovery of a remarkable snake
10 How to help geckos adapt to a new area
11 Owls help to identify rare invertebrates
12 New climbing method observed in invasive tree snake
14 Giant prehistoric crocodile discovered
15 How flying reptiles evolved
18 Being heard above the noise
20 Magnetic switch defends against snake venom
21 Venom serves a defensive purpose
22 Helping the survival of young crocodilians
24 How frogs can fight off fungus
26 Differences in movement amongst snakes
29 Revealed: the deepest-nester of all vertebrates
30 Secrets of the most deadly rattlesnake revealed
32 Snakes versus lizards
34 Bee bounces back
35 A colourful battle for survival
36 A new type of reptile discovered
37 How papillomas spread in turtles
38 Egg-laying behaviour in loggerhead sea turtles aids survival
40 New millipede discovered in a very unusual locality
42 The oldest skink in Australia
44 A praying mantis from the age of the dinosaurs
46 New deadly snake discovered in Asia
48 Breakthrough in our understanding of sex determination in bearded dragons
49 The truth revealed: yes, snakes are slimy!
50 Types of teeth indicate dietary changes
52 Tortoises hatch with a natural attraction to faces
53 Turtles locate an invisible ocean corridor
56 Why do tarantulas have such a wide distribution?
58 Egg colour competition
60 New fanged frog found
62 Big bumblebees begin foraging early
63 Tree-dwelling pterosaur with a distinctive thumb
64 Living in a world full of killer giant crocodilians
66 The mystery of the 'lost years' is solved?
68 The horned crocodile of Madagascar
70 A flying reptile with a neck longer than that of a giraffe
72 The relationship between snake diets and venom
74 New discoveries about dart frog breeding behaviour
76 Why wall lizards have thrived
78 A gnawing issue!
82 Unique findings on São Tomé island
84 Sea snakes have a sensitive side
86 Tiny lizard's identity confirmed
88 Snake-killing spiders
90 Rattlesnakes may benefit from global warming
92 How studies don't always work out
94 Snake monitors
96 Driven to survive with similar strategies
98 The amazing discovery of a new moth
100 Tourism may represent a danger to tortoises
101 New Australian crocodile found
102 Investigating leopard gecko colours
104 Life-saving snake venom
106 Reptiles suffer a mass extinction
108 Deadly spider venom to save heart attack victims?
110 How a gecko copes after losing its tail
112 Gopher tortoise studies
114 Mediterranean sea turtles recover
115 Smaller turtles nesting on Florida's beaches
116 New stunning dragon-like lizard discovered
118 The survival of snakes
120 Resistant lizards
122 Crash-landing geckos
125 A new resident in Florida?
126 Investigating sticky toe pads
128 Pterosaurs flew from hatching
130 Critical information for conserving rainforest lizards
132 At the cusp of dental evolution
133 How snakes got their fangs
134 New salamander discovered
136 People's perceptions of rattlesnakes investigated in a collaborative study
138 A single turtle survived the northern hemisphere's mass extinction
140 Earlier springs can adversely affect amphibians
142 Threatened rattlesnakes - the impact of inbreeding
144 Missing link dismissed
146 Feared extinct: the only frog with true teeth on its lower jaw
148 Live long and prosper
150 A long-distance traveller?
152 How spiders are programmed to build webs
154 Plastic creates 'evolutionary trap' for young sea turtles
156 Gigantic flying reptile found in Australia
158 New species found
160 A millipede as big as a car
162 Snakes benefited from the mass dinosaur extinction

New hope for previously doomed turtle species



The recently-discovered female - the only confirmed example of its gender alive today. Photo courtesy Stephen Sautner/Wildlife Conservation Society.

➤ **Robert Swinhoe (1836-1877), after whom the turtle is named.** Source PD.

Swinhoe's softshell turtle (*Rafetus swinhoei*), which is also known as the Yangtze giant softshell turtle and the Red River giant soft-shell turtle, is the rarest aquatic chelonian in the world. It was seemingly destined to die out following the death of the last known female in April 2019. This left just a male, believed to be about a century old, in Suzhou Zoo, China, as far as was known with certainty.

As its name suggests, this is a massive turtle, which has been documented as growing to more than 100cm (39in) in length, with a shell width of up to 70cm (28in). Individuals have been known to weigh as much as 247.5kg (546lb), with the largest members of the species generally documented from the Vietnamese part of their range. Their distribution was centred on an area in eastern China, including the Yangtze River and Lake Tai, and also in a region further south in the country, extending across the border into northern Viet Nam.

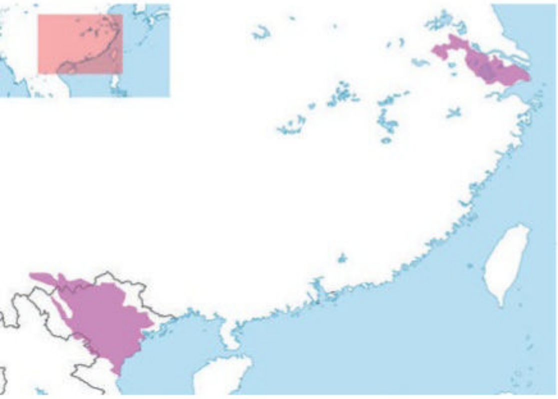
The species was first made known to science by the English diplomat and naturalist Robert Swinhoe when he was working in mainland China and sent a specimen back during 1873 to the British Museum in London. Sadly, a combination of factors, ranging from direct hunting and fishing through to aquatic pollution subsequently triggered a critical decline in the numbers of this species. The last individual seen in the wild in China was caught back in 1998, and then released. No further sightings there have since been recorded.

A new pairing is possible!

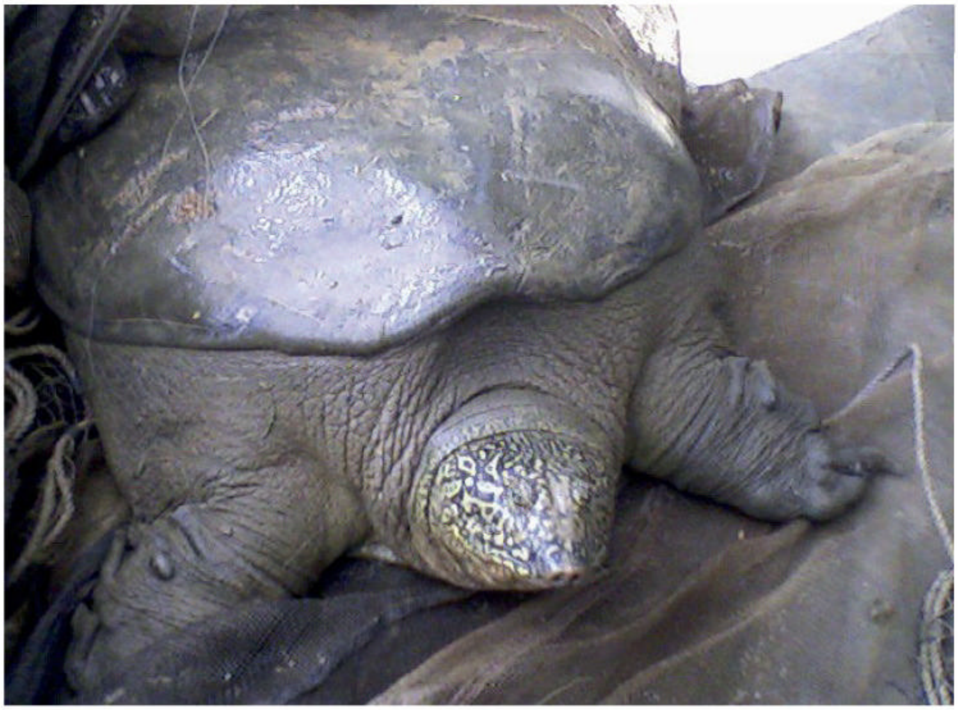
Now in an incredibly exciting development, however, the Ha Noi Department of Agriculture and Rural Development, in collaboration with the Asian Turtle Program (ATP) of Indo-Myanmar Conservation (IMC) and the Wildlife Conservation Society (WCS) have made dramatic progress, which could yet hopefully prevent the extinction of this species. Scientists have just revealed that genetic testing confirmed a female turtle captured late last year in Viet Nam's Dong Mo Lake is definitively a Swinhoe's softshell turtle.

This confirmation means there is now one known male Swinhoe's softshell turtle at Suzhou Zoo in China; and also this new female from Ha Noi, Viet Nam. It is also believed that there is at least one more of these turtles in Dong Mo Lake and another in nearby Xuan Khanh Lake. Conservationists hope to catch and determine the sex of the other turtles in both these lakes during this coming spring.

Ultimately, the aim is to ensure at least one male and female are given a chance to breed, with the aim of ensuring that this species can return from the brink of extinction. What is particularly exciting is the reproductive



⮝ **The previously-known distribution of Swinhoe's softshell turtle.** Source : *IUCN Red List of Threatened Species*. Map courtesy Bookworm8899/CC BY-SA.



⮝ **Swinhoe's softshell turtle retains a brightly coloured head pattern, and has the typically extended nostrils, as commonly associated with members of this group. These serve rather like snorkels, allowing the turtle to raise its head in shallow water and breathe without being conspicuous.** Photo courtesy Phuongcacanh at Vietnamese Wikipedia/CC BY-SA 3.0.

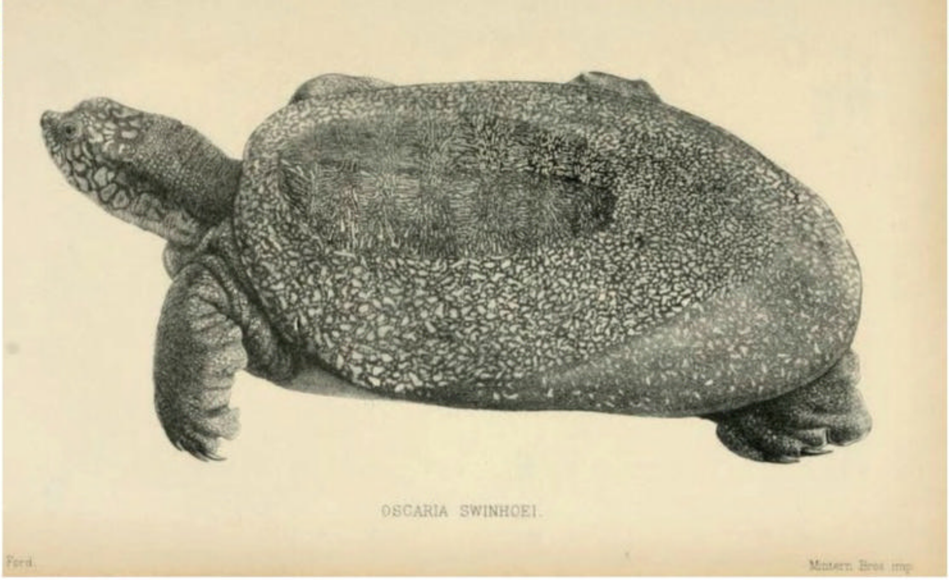

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Illustration of the Swinhoe's softshell turtle sent by Robert Swinhoe to John Edward Gray at the British Museum. From a publication by Gray in 1873. Source PD.

potential of these turtles, as females are known to lay large clutches, numbering anywhere from 20 to 80 or more eggs at a time. This could clearly provide a way to build up numbers again quickly.

The way forward

Nguyen Huy Dang, Deputy Director of Ha Noi Department of Agriculture and Rural Development, explains: "This is a very important mission and it needs to be done effectively. We have been seeking advice and consultation from the Ha Noi People's Committee to promulgate guiding documents and collaboration with international organisation to execute our development and conservation plan of *Rafetus swinhoei*. The department of Ha Noi Fisheries continues to implement the Plan #200 from the Ha Noi People's Committee to revive and preserve the Swinhoe's softshell turtle, a rare, precious and endangered species in the red book of Viet Nam and in the world."

In addition, Timothy McCormack, Program Director of the ATP/IMC, says: "It is so important that we are taking these steps, confirming the sex of the identified animals, and in the case of the animal in Xuan Khanh Lake, confirming the species, as currently this has only been based on environmental DNA. Once we know the sex of the animals in Viet Nam, we can make a clear plan as to the best way forward.

"Hopefully we have a male and a female, in which case breeding and recovery of the species becomes a real possibility. At the same time our surveys in other areas of Viet Nam suggest other animals might still survive in the wild, and we need to be looking at bringing these together as part of the broader conservation plan for the species."

Optimism for the future

WCS Viet Nam Country Director Hoang Bich Thuy adds: "In a year full of bad news and sadness across the globe, the discovery of this female can offer all some hope that this species will be given another chance to survive. Overhunting and habitat destruction have contributed to the demise of this species. In Viet Nam, with the leadership of the government, we are determined to take responsibility to give this species another chance."

"This is the best news of the year, and quite possibly the last decade, for global turtle conservation. As the most endangered turtle on Earth, a tremendous amount of energy and resources have been dedicated to the preservation of Swinhoe's softshell turtle," adds Andrew Walde, Chief Operating Officer of the Turtle Survival Alliance, a technical advisor on this project.

"Following the loss of the only known female at the time in 2019, the confirmation of this wild specimen as female is a cause for celebration for all those who have worked tirelessly to see this turtle species survive. We commend the dedication and leadership of the Viet Nam Government, Ha Noi DARD, and our colleagues at ATP and WCS. We look forward to continuing to provide technical expertise to the project in 2021, and for on-going success."

Past difficulties

Prior to this discovery, there had been a major effort to breed the last two known remaining members of the species. Then, the last known female Swinhoe's softshell turtle died on April 13, 2019, during recovery from anaesthesia after an artificial insemination procedure in Suzhou, China. This was necessary because of serious long-standing damage caused to the male's reproductive organs prior to them being introduced.

The male and female turtles, which had failed to produce offspring naturally since they were brought together in 2008, were determined to be healthy for the procedure, and similar anaesthesia procedures had previously been performed without incident. When the female died, hope for the species turned to the possible reports of additional turtles in two different lakes in Viet Nam, called Dong Mo Lake and Xuan Khanh Lake.

Since early 2019, with technical support from the ATP/IMC and WCS, Ha Noi Fisheries Department had organised various consultations and review meetings to develop a technical approach for the discovery and capture of the turtles; conduct more surveys of Dong Mo Lake; and select trapping locations. The plan was delayed due to COVID-19 lockdowns in Viet Nam, preventing international team members, including veterinary staff and turtle experts, travelling to Viet Nam because of travel restrictions.

With no sightings in the Yangtze river for over 20 years, it seems highly likely that the species is now extinct there. Hope for its survival is focused on tracking down surviving Vietnamese individuals.
Photo courtesy Daniel Doerfler/www.shutterstock.com

It is thought there could be at least one more turtle in Viet Nam's Dong Mo Lake, but finding it in this massive body of water will not be easy.
Photo courtesy NguyyenQuocThang/www.shutterstock.com

Perseverance pays off!

Finally, in September 2020, a team went back into the field, and included local fisherman, the Ha Noi Fisheries Department and the ATP/IMC and WCS personnel. They spent weeks putting out a series of nets in the large 1400ha lake (equivalent to 3459 acres), creating a fenced-in 90ha (222 acre) capture zone. On October 22, 2020, a turtle was seen next to the net fence and a quick-thinking team member was able to capture it with the help of a local fisherman.

A temporary holding pond had already been prepared on a small island in the lake and a veterinary team from ATP/IMC and WCS arrived in a matter of hours. In addition, an international veterinarian working for Four Paws Viet (a bear rescue center) brought ultrasound equipment to allow the turtle to be sexed. With close coordination and technical support from the capture and animal care teams, a health check was carried out on the following day.

Various swabs and samples were also taken, with the ultrasound examination being carried out, a microchip was inserted, and the details of the physical check were recorded. The turtle weighed in at 86kg (189.5 pounds) and was 1m (3.2 feet) in length. To everyone's great relief, she was healthy, strong and keen to get back in the lake where she was released on the same day.

At the recent Ha Noi workshop, the genetic results from the tests confirmed this turtle was indeed a female Swinhoe's softshell turtle (*Rafetus swinhoei*). This forensic examination was carried out by the Institute of Ecology and Biological Resources of the Viet Nam Academy of Science and Technology, with the independent gene analysis being undertaken by the Department of Natural Resources and Conservation, the Central Institute for Natural Resources and Environmental Studies, Viet Nam National University (VNU CRES) in Ha Noi.

Future plans

With sightings of a second turtle with an estimated weight of 130kg (286lb) in Dong Mo Lake, additional work started in November 2020 with the capture team, which undertook simulation exercises involving different trapping methods. The plan currently is to try and catch this other individual, enabling its identity to be confirmed at the lake in spring of 2021, when the water level in the lake should be at the lowest. Teams are hoping that it will be a male, significantly increasing the likelihood that the world's rarest species of turtle can mate and produce offspring in either a semi-wild area or in a captive-breeding facility in Viet Nam.

⮝ The outcome of the genetic testing was announced at a recent workshop held in the Vietnamese city of Ha Noi.
Photo courtesy NguyyenQuocThang/www.shutterstock.com

Why crocs have not changed a lot

New research by scientists at the University of Bristol explains how a 'stop-start' pattern of evolution, governed by environmental change, could explain why crocodiles have changed so little since the age of the dinosaurs.

Crocodiles today look very similar to ones from the Jurassic period some 200 million years ago. There are also relatively few species alive today – just 25, as far as is known.

Much greater diversity in the past

Other groups of creatures such as lizards and birds have achieved a diversity of many thousands of species during the same period of time or less. But it appears that crocodiles have gone backwards, in terms of the number of forms and the diversity existing within this group of reptiles. Prehistory records various types of crocodile that we don't see today, including giants as big as dinosaurs, some that were at home on land, serpentine marine forms and even plant-eaters!

In their new research, the scientists explain how crocodiles follow a pattern of evolution known as 'punctuated equilibrium'. The rate of their evolution is generally slow, but occasionally they evolve more quickly because the environment has changed. In particular, this new research suggests that their evolution speeds up when the climate is warmer, and that their body size increases at this stage.

Dr Max Stockdale, from the University of Bristol's School of Geographical Sciences, explains: "Our analysis used a machine-learning algorithm to estimate rates of evolution. Evolutionary rate is the amount of change that has taken place over a given amount of time, which we can work out by comparing measurements from fossils and taking into account how old they are.

"For our study, we measured body size, which is important because it interacts with how fast animals grow, how much food they need, how big their populations are and how likely they are to become extinct."

A distinctly recognisable fossilised crocodile, called *Crocodilemus robustus*, which lived about 160 million years ago. Photo courtesy Dinoton/www.shutterstock.com

An adaptable design

The findings show that the limited diversity of crocodiles and their apparent lack of evolution is a result of a slow evolutionary rate. It seems the crocodiles arrived at a body plan that was very efficient and versatile enough so that they didn't need to change it in order to survive.

This versatility could be one explanation why crocodiles survived the meteor impact some 66 million years ago at the end of the Cretaceous period, in which the dinosaurs perished. Crocodiles generally thrive better in warm conditions because they cannot control their body temperature and require warmth from the environment.

The gharial is the most distinctive member of the crocodilian group alive today, but aside from the narrowing of its snout, which is thought to make it easier to prey on fish, the overall body size and shape is unmistakably crocodilian, extending back millions of years in the fossil record. Photo courtesy Samuel Bloch/www.shutterstock.com

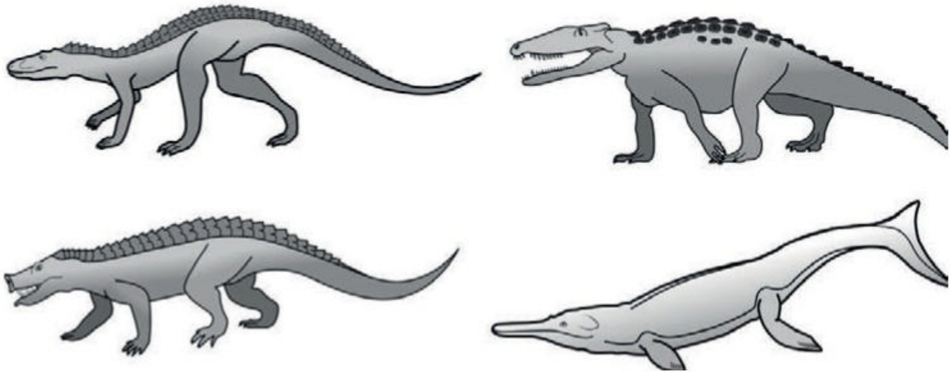
The basic body plan of crocodiles has not diverged greatly over the course of millions of years.
Photo courtesy Mariya Serezhkina/www.shutterstock.com

The climate during the age of dinosaurs was warmer than it is today, and that may explain why there were many more varieties of crocodile than we see now, including some of the largest crocodiles ever recorded. Being able to draw energy from the sun means crocodiles do not need to eat as much as a warm-blooded animal like a bird or a mammal.

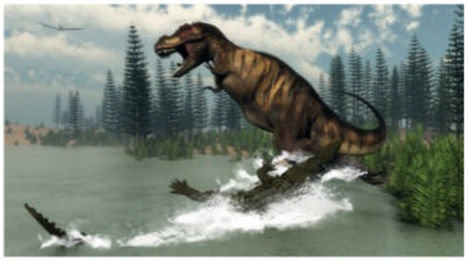
Further research

Dr Stockdale added: "It is fascinating to see how intricate a relationship exists between the earth and the living things we share it with. The crocodiles developed a lifestyle that was versatile enough to adapt to the enormous environmental changes that have taken place since the dinosaurs were around."

The next step for the team's research is to find out why some types of prehistoric crocodile died out, while others have continued to thrive through to the present day. It seems strange that there are no specific marine crocodiles for example, in the world's tropical oceans. Might this reflect a shortage of suitable prey perhaps?



Crocodiles have existed in a much greater range of forms in the past. These include fast runners, digging and burrowing forms, herbivores, and ocean-dwelling species. Artwork courtesy University of Bristol.



Deinosuchus, thought to be the largest member of the crocodile clan ever to exist, growing to a potential length of 12m (39ft), shown here attacking the dinosaur *Tyrannosaurus rex*. Artwork courtesy Elenarts/www.shutterstock.com

Further information

Maximilian T. Stockdale, Michael J. Benton. **Environmental drivers of body size evolution in crocodile-line archosaurs.** *Communications Biology*, 2021; 4 (1) DOI: 10.1038/s42003-020-01561-5

The strange discovery of a remarkable new species of snake

Jeff Weinell holds a specimen of the Waray dwarf burrowing snake which his research identified. Photo courtesy University of Kansas.

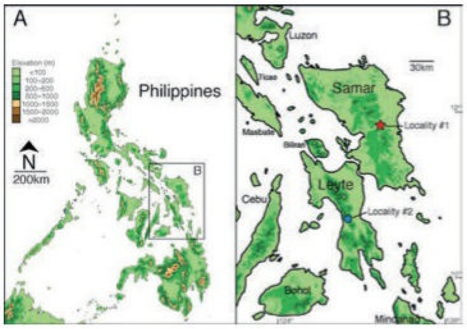
In all honesty, the newly-described Waray dwarf burrowing snake (*Levitonius mirus*) is pretty good at hiding. In its native habitat on the Philippine islands of Samar and Leyte, the snake spends most of its time out of sight, living underground. It typically only surfaces after heavy rains, in much the same way as earthworms tend to emerge on lawns in suburban areas after a downpour.

An overlooked brown snake!

It may not therefore be surprising that when examples of the Waray dwarf burrowing snake were collected in 2006 and 2007, they were misidentified in the field — nobody had seen them before. The specimens then spent years preserved in the collections of the University of Kansas (KU) Biodiversity Institute and Natural History Museum, overlooked by researchers who were unaware they possessed an entirely new genus of snake, even after further examples were found in 2014.

But that changed once Jeff Weinell, a KU graduate research assistant at the Biodiversity Institute, took a closer look at the specimens' genetics using molecular analysis, before sending them to collaborators at the University of Florida for CT scanning. Now, he is responsible not just for discovering a new species of snake, but a whole new genus.

"I was initially interested in studying the group of snakes that I thought it belonged to — or that other people thought it belonged to," Weinell admits. "This is when I first started my PhD at KU. I was interested in collecting data on a lot of different snakes and finding out what I actually wanted to research. I knew this other group of small, burrowing snakes called *Pseudorabdion* — there are quite a few species in the Philippines — and I was interested in understanding the relationships among those snakes. So I made a list of all the specimens we had in the museum of that group, and I started sequencing DNA for the tissues that were available."



The adjacent islands of Samar and Leyte lie in the central-eastern area of the Philippines. Areas where the snake was discovered are highlighted on map B. Illustrations courtesy Weinell *et al*.

The landscape of the Philippines where these newly-recognised snakes live, on the island of Samar. Photo courtesy Tatiana Nurieva/www.shutterstock.com

The clarity of DNA testing

As soon as Weinell got the molecular data back, he realised the sample from the subterranean snake didn't fall within the existing *Pseudorabdion* genus. But pinpointing where the snake should be classified wasn't a simple task. The Philippine archipelago is an exceptionally biodiverse region that includes at least 112 species of land snakes, representing 41 genera and 12 families.

"It was supposed to be closely related, but it was actually related to another entirely different family of snakes," he explains. "That led me to look at it in more detail, and I recognised that there were actually some features that were quite different from the group it was initially identified as belonging to."

Working with Rafe Brown, professor of ecology & evolutionary biology and curator-in-charge of the KU Biodiversity Institute and Natural History Museum, Weinell took a closer look at the snake's morphology, paying special attention to the scales on the body, which can be used to differentiate species.

Fewer vertebrae than any other living snake

He then sent one of the specimens to the University of Florida for CT scanning to get a more precise look at the internal anatomy of the mysterious Philippine snake. The CT images turned out to be surprising.

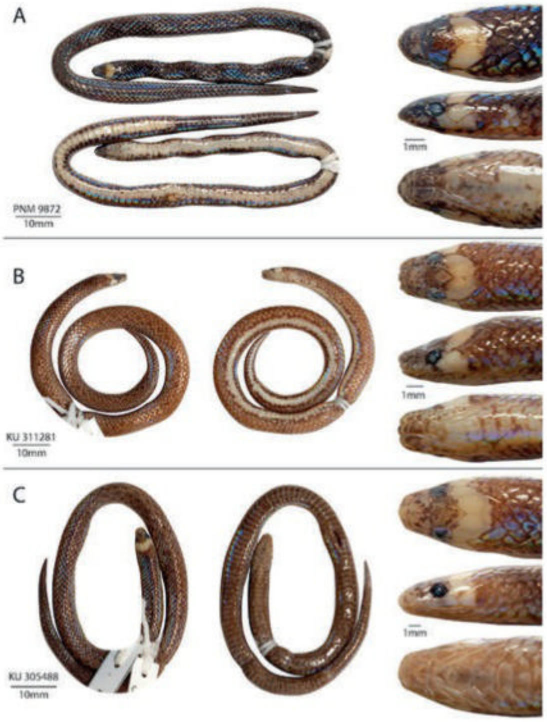
"The snake has among the fewest number of vertebrae of any snake species in the world, which is likely to be the result of miniaturisation and an adaptation for spending most of its life underground," Weinell reveals.

Finally, the KU graduate research assistant and his colleagues were able to determine the Waray dwarf burrowing snake represented both a new "miniaturised genus" and an unidentified species of snake. Now Weinell has had the chance to bestow the snake with its scientific name: *Levitonius mirus*.

"It's actually named for Alan Leviton, who is a researcher at the California Academy of Sciences, and he had spent decades basically studying snakes in the Philippines in the '60s, '70s, '80s and then all the way up to now," Weinell explains. "So that's sort of an honourific genus name for him. Then 'mirus' is Latin for 'unexpected'. That's referencing the unexpected nature of this discovery — getting the DNA sequences back and wondering what was going on!"

⮝ Land clearance for agriculture is a problem that affects the future of many of the endemic species - often restricted to individual islands - on the Philippines. Photo courtesy JA Ritnetikun/www.shutterstock.com

⮝ There is a wide diversity of snakes spread across the Philippine islands - many species are endemic, being found nowhere else in the world, such the samar or southern Philippine cobra (*Naja samarensis*) seen here. Photo courtesy ccarbill/www.shutterstock.com



⮝ Three example specimens of the Waray dwarf burrowing snake (*Levitonius mirus*). Photo courtesy Weinell et al.

The benefit of a second glance

Weinell's colleagues involved in this research included Daniel Paluh from the University of Florida and Cameron Siler of the University of Oklahoma. Professor Brown himself is keen to point out that the description of *Levitonius mirus* highlights the value of preserving collections of biodiversity in research institutions and universities.

"In this case, the trained 'expert field biologists' misidentified specimens — and we did so repeatedly, over years — failing to recognise the significance of our finds, which were preserved and assumed to be somewhat unremarkable, nondescript juveniles of common snakes," he says. "This happens a lot in the real world of biodiversity discovery.

"It was only much later, when the next generation of scientists came along and had the time and access to accumulated numbers of specimens, and when the right people, like Jeff, who asked the right questions and those who have the right tools and expertise, like Dan, took a fresh look, that we were finally able to identify this snake correctly. It's a good thing we have biodiversity repositories and take our specimen-care oaths seriously."

Much still to learn…

Marites Bonachita-Sanguila, a biologist at the Biodiversity Informatics and Research Center at Father Saturnino Urios University, located in the southern Philippines, says the snake discovery "tells us that there is still so much more to learn about the reptile biodiversity of the southern Philippines by focusing intently on species-preferred microhabitats.

"The pioneering Philippine herpetological work of Walter Brown and Angel Alcala from the 1960s to the 1990s taught biologists the important lesson of focusing on species' very specific microhabitat preferences," Bonachita-Sanguila explains. "Even so, biologists have really missed many important species occurrences, such as this, because …. well, simply because we did not know the basic clues about where to find them.

"In the case of this particular discovery, the information that biologists lacked was that we should dig for them when we survey forests. So simple. How did we miss that? All this time, we were literally walking on top of these reptiles as we surveyed the forests of Samar and Leyte. Next time, bring a shovel!"

She added that habitat loss as a result of land use pressure (such as conversion of forested habitats for agriculture to produce food for people) is a prevailing issue in Philippine society today. "This new information, and what we will learn more in future studies of this remarkable little creature will inform planning for conservation action, reflecting the strong need for initiatives to conserve Philippine endemic species — even ones we seldom get to see.

"We need effective land-use management strategies, not only for the conservation of celebrated Philippine species like eagles and tarsiers, but for lesser-known, inconspicuous species and their very specific habitats — in this case, forest-floor soil, because it's the only home they have."

Further information

Jeffrey L. Weinell, Daniel J. Paluh, Cameron D. Siler, Rafe M. Brown. A New, **Miniaturized Genus and Species of Snake (Cyclocoridae) from the Philippines**. *Copeia*, 2020; 108 (4) DOI: 10.1643/CH2020110

How to help geckos adapt to a new area

University of Otago researchers have added another piece to the puzzle about how best to translocate New Zealand lizards for conservation purposes – confine them! Department of Zoology researchers translocated 19 barking geckos to Mana Island, using the method of penned release – enclosing them in a pen with an area of 100 sq m (1076 sq ft) for three months so they would get used to the site and hopefully establish a breeding population.

⮝ The Wellington green gecko (*Naultinus punctatus*) was the subject of this study. Photo courtesy reptiles4all/www.shutterstock.com

⮜ Dr Jo Monks hopes this research will mark a new era in being able to move - or translocate - reptiles successfully. Photo courtesy Dr Jo Monks.

Valuable insights

It was the first time that such a method had been used with this species and the researchers found it worked well. The geckos' area use decreased over time, indicating they had established territories.

Dr Jo Monks, Otago Honorary Research Fellow and Department of Conservation Science Advisor, says translocations of reptiles and amphibians have, historically and globally, been notoriously unsuccessful in the past. However, a recent penned release success with jewelled geckos prompted her team to try with a different species.

"By understanding the behavioural response of barking geckos to a penned release, this research is helping us to appreciate which techniques best help a new population of geckos to become established, following translocation to a new site," she explains.

A beautiful and iconic group of lizards

Barking geckos (*Naultinus punctatus*) are one of nine species of green gecko (or moko-kākāriki in the Maori language) that are only found in New Zealand (Aotearoa). They are considered 'At Risk – Declining' under New Zealand's Threat Classification System.

Many green gecko populations have already undergone a decline in numbers and locations where they can be seen as a result of predation (especially by introduced species), habitat modification, and poaching, but little research on their ecology exists.

"Protecting barking geckos and the other reptiles of Aotearoa is important in its own right and for the mauri of ecosystems in which they have key roles as pollinators and seed dispersers, as well as being predators of invertebrates and the prey of larger animals," Dr Monks explains.

"There is potential for penned release schemes to work for a wide range of fauna, in cases where initial dispersal following translocation could be detrimental to establishing the species in a particular environment. We now know it can be used successfully with these geckos."

⮝ Gray's tree gecko (*N. grayii*), also known as the Northland green gecko, based on the area of New Zealand where it occurs north of Whangaroa, is currently one of the most threatened species within the group. Photo courtesy reptiles4all/www.shutterstock.com

⮝ The distinctive colouration of this group of geckos helps them to blend into the background. This jewelled individual (*Naultinus gemmeus*) was encountered resting on New Zealand's Otago Peninsula.
Photo courtesy Cormac Price/www.shutterstock.com

Further information

Tom Flynn-Plummer, Joanne Monks. **Penned release reduces area use by translocated barking geckos (*Naultinus punctatus*).** *New Zealand Journal of Ecology*, 2021; DOI: 10.20417/nzjecol.45.17

Owls help to identify rare invertebrates

The feeding habits of birds can be an invaluable tool for research into the distribution and conservation of their prey, such as overlooked and rare bush cricket species, according to scientists studying the diet of the Eurasian eagle owl (*Bubo bubo*) in southeastern Bulgaria.

Dr Dragan Chobanov, based at the country's Institute of Biodiversity and Ecosystem Research and Dr Boyan Milchev from the University of Forestry report the frequent presence of the threatened big-bellied glandular bush cricket (*Bradyporus macrogaster*) in the diet of Eurasian eagle owls, and conclude that the predatory bird could be used to identify biodiversity-rich areas where the cricket is present which are in need of protection.

A site of significance

While the Balkan Peninsula has already been recognised as the area with the highest diversity of orthopterans (grasshoppers, crickets and bush crickets) in Europe and one of the generally most biologically diverse areas in the whole Palearctic realm, it is also home to a worrying number of threatened species.

Additionally, a thorough and updated country assessment of the conservation status of the orthopterans found in Bulgaria is currently lacking.

This is why the Bulgarian team undertook a study on the biodiversity of these insects by analysing food remains from the pellets of Eurasian eagle owls, collected from 53 different breeding sites in southeastern Bulgaria.

As a result, the scientists reported three species of bush crickets that have become a significant part of the diet of these predatory birds. Curiously enough, all three species are rare or threatened in Bulgaria. The case of the big-bellied glandular bush cricket (*Bradyporus macrogaster*) is of special concern, as it is a species threatened by extinction.

The location of the Balkan peninsula. Map courtesy Itan1409/www.shutterstock.com

A male specimen of the big-bellied glandular bush cricket. Photo courtesy Dragan Chobanov.

Eurasian eagle owls are changing their hunting habits and seeking out more invertebrates.
Photo courtesy Richard Whitcombe/www.shutterstock.com

Environmental changes and monitoring

The local decline in mammals and birds that weigh between 0.2-1.9kg (0.44-4.1lb), which are in fact the preferred prey of the Eurasian eagle owl, has led this highly opportunistic predator to switch increasingly to seeking out large insects as food. The researchers even suspect that there might be more overlooked species attracting the owls.

***Bradyporus* bush crickets are large in size, as shown here with this cricket on a boy's hand.**
Photo courtesy ATTILA Barsan/www.shutterstock.com

It is hoped that these interconnected findings, and the threatened status of the big-bellied glandular bush-cricket, a species with a crucial role in the food chain, will prompt the designation of a new protected Natura 2000 site in the region. Additionally, due to the bush cricket's requirements for habitats where there is a wide range of vegetation and little disturbance, combined with its relatively large size and the ease with which males can be found thanks to their song, so the scientists also suggest it is an ideal indicator of habitat quality and the health of the wider ecosystem.

Further information

Dragan Chobanov, Boyan Milchev. **Orthopterans (Insecta: Orthoptera) of conservation value in the Eurasian Eagle Owl *Bubo bubo* food in Bulgaria.** *Travaux du Muséum National d'Histoire Naturelle "Grigore Antipa"*, 2020; 63 (2): 161 DOI: 10.3897/travaux.63.e53867

New climbing method observed in invasive tree snake

Researchers have discovered that invasive brown tree snakes (*Boiga irregularis*) living on the Pacific island of Guam can get around in a way that had never been seen before. The discovery of the snake's lasso-like locomotion for climbing their way up smooth vertical cylinders has important implications, both for understanding the snakes and for conservation practices aimed at protecting birds from them.

"Our most important finding is a new mode of snake locomotion," says Julie Savidge of Colorado State University (CSU). "Only four major types have been recognised for nearly 100 years, and we now have discovered a fifth mode."

The discovery of this new method of locomotion – in additional to the known rectilinear, lateral undulation, sidewinding, and concertina modes – came about by chance. Savidge was working on a project aimed at protecting the nests of Micronesia starlings, which represent one of only two native forest bird species still remaining on Guam.

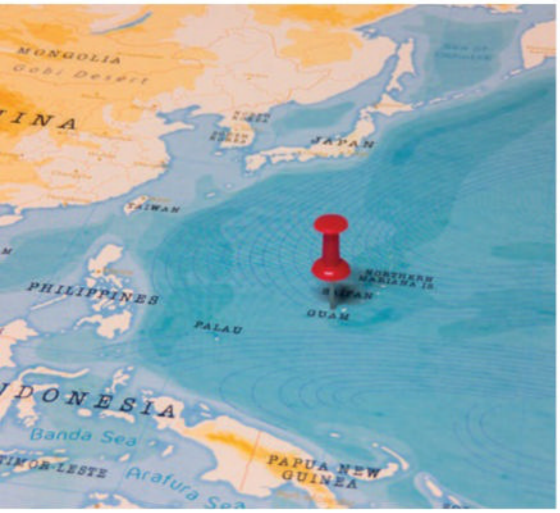
The impact of these snakes

People accidentally introduced the nocturnal snakes to Guam in the late 1940s or early 1950s. Shortly thereafter, bird populations started to decline and it's now recognised that the invasive snakes have decimated forest bird populations on the island. They are also responsible for extensive damage and many power outages across the island each year.

"Most of the native forest birds are gone on Guam," says Savidge. "There's just a relatively small population of Micronesian starlings and another cave-nesting bird that have survived in small numbers."

⮝ **A brown tree snake – as its name suggests, this species can climb well.** Photo courtesy Janelle Lugge/www.shutterstock.com

It is thought that the brown tree snake was inadvertently taken to Guam by US military personnel after the end of the Second World War. The snake itself is native to parts of Australia, New Guinea and other islands in the region, but faced no competition on Guam, where there are no native snakes. Photo courtesy reptiles4all/www.shutterstock.com



⮟ **Guam is a US territory, lying in the western region of the Pacific Ocean.** Map courtesy hyotographics/www.shutterstock.com

Trying to protect bird life

"Understanding what brown tree snakes can and cannot climb has direct implications for designing barriers to reduce the dispersal and some of the harmful effects of this highly invasive species," says her colleague Bruce Jayne, from the University of Cincinnati.

In the new study, the researchers were attempting to use a metal baffle approximately 1m (3ft) long, so as to prevent the brown tree snakes from climbing up to bird boxes. The same baffles have been used successfully to keep other snakes and raccoons away from nest boxes in the gardens of birdwatchers. But, they soon found their ability to deter brown tree snakes was rather short-lived.

"We didn't expect that the brown tree snake would be able to find a way around the baffle," Seibert says. "Initially, the baffle did work, for the most part. Martin Kastner, a CSU biologist, and I had watched about four hours of video and then all of a sudden, we saw this snake form what looked like a lasso around the cylinder and wiggle its body up. We watched that part of the video about 15 times. It was a shocker. Nothing I'd ever seen compares to it."

⮝ **Just two out of 14 bird species have evaded being wiped out by the brown tree snake on Guam, with the Micronesian starling (*Aplonis opaca*) seen here being one of them.** Photo courtesy Stubblefield Photography/www.shutterstock.com

How the lasso operates

Jayne explains that snakes typically climb steep, smooth branches or pipes using concertina locomotion, bending sideways to grip in at least two places. But lasso locomotion is different. Using the loop of the lasso, the snakes have a single gripping region.

By recording and carefully analysing high-resolution video of this new climbing method, the researchers found that the snakes have these little bends within the loop of the lasso. Those bends allow them to advance slowly upwards, by shifting the location of each bend.

That's not to say this way of climbing isn't a struggle for the snakes. In the process of their lasso locomotion, the researchers observed the snakes moving quite slowly. They also slip often, stop to rest, and breathe heavily.

"Even though they can climb using this mode, it is pushing them to the limits," Jayne says.

Hope for the future

"Now given that brown tree snakes can use lasso locomotion to defeat poles or cylinders of a certain size, we can design baffles to better protect bird houses used for restoring some of Guam's birds," explains fellow researcher Thomas Seibert, who is also based at CSU,

Savidge and Seibert are planning to continue with the development of a baffle that brown tree snakes can't get around, which could then be used on Guam. Jayne plans to test in more detail what brown tree snakes can and cannot traverse. He also wants to test the limits of the locomotor abilities of other snake species and learn more about the anatomy and physiology involved.

Further information

Savidge *et al*. **A novel mode of locomotion expands the climbing abilities of snakes.** *Current Biology*, 2021 DOI: 10.1016/j.cub.2020.11.050

⮝ **The adaptability of these snakes has had a devastating impact on the biodiversity within Guam's forests. Birds are important seed dispersers in the tropics especially, and the longer term future for the island's wooded areas is of concern.** Photo courtesy Dr Kevin Kim/www.shutterstock.com

Giant prehistoric crocodile discovered

The Indo-Pacific crocodile is the largest living species in Australia today. Photo courtesy Napaphat/ www.shutterstock.com

A prehistoric crocodile measuring more than 5m (16.5ft) long – dubbed the 'swamp king' – was the dominant predator in Australia's southeastern Queensland waterways only a few million years ago. Researchers from the University of Queensland have identified this new species of crocodilian, which is now known to science as *Paludirex vincenti*, from fossils first unearthed during the 1980s.

More intimidating than a 'saltie' today

Jorgo Ristevski, based at the UQ's School of Biological Sciences, explains the species was named after Geoff Vincent who discovered the giant fossilised skull near the town of Chinchilla. "In Latin, 'paludirex' means 'swamp king', and 'vincenti' honours the late Mr Vincent," Ristevski explains.

"For several years, the fossilised skull was on display in the Queensland Museum, before it was donated to the Chinchilla Museum in 2011.

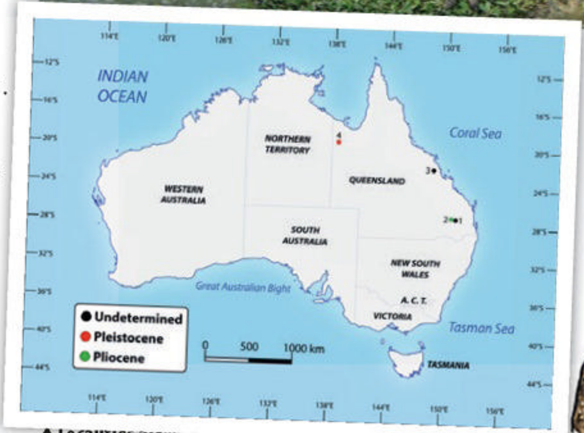
There is no doubt that the 'swamp king' was clearly an intimidating crocodile. "We calculated its likely overall length based on the size of its fossilised skull, which measures around 65cm (26in)," says Jorgo Ristevski. "The largest member of the group alive today is the Indo-Pacific crocodile (*Crocodylus porosus*), which grows to about the same length, but paludirex had a broader, more heavy-set skull so it would have resembled an Indo-Pacific crocodile on steroids!"

A different landscape

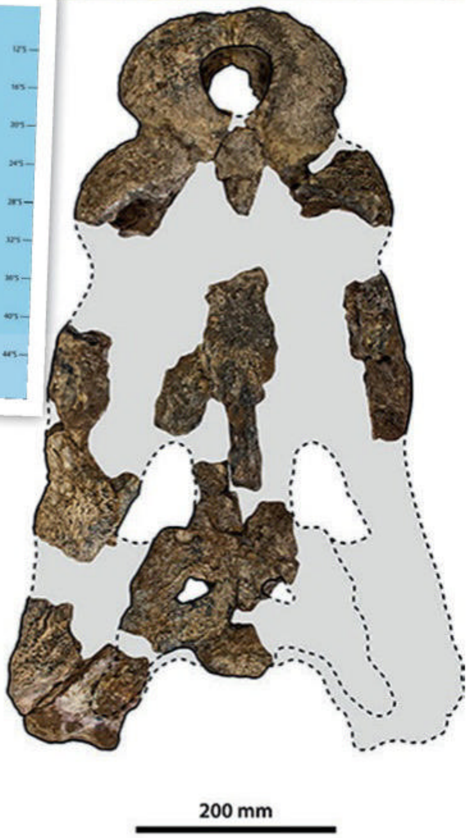
Paludirex was one of the top predators in Australia a few million years ago, capable of preying on giant prehistoric marsupials. "The waterways of the Darling Downs would once have been a very dangerous place because of it," he adds.

Ristevski's colleague, Dr Steve Salisbury emphasises that various species of prehistoric crocodylians had existed in Australia. "Crocs have been an important component of Australia's fauna for millions of years," he emphasises. "But the two species we now have today — the Indo-Pacific species and Johnston's (*Crocodylus johnstoni*) — are only relatively recent arrivals, and were not part of the endemic crocodile fauna that existed here from about 55 million years ago.

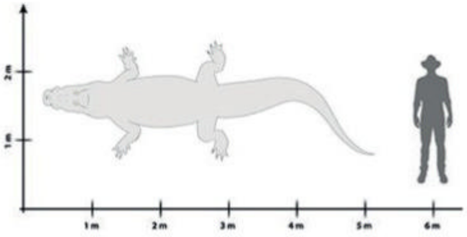
"Whether *Paludirex vincenti* went extinct as a result of competition with species like *Crocodylus porosus* is hard to say. The alternative is that its demise may have resulted from climate change, which led to a drier environment, causing the river systems which it once inhabited to contract significantly. We're currently investigating both scenarios.



Localities across Queensland, Australia [illegible] remains of paludirex have been unearthed. 1. Darling Downs region, near Warra; 2. Chinchilla (found by Geoff Vincent); 3. Nebo district, near Mackay; 4. Terrace Site, Riversleigh. Map courtesy Jorgo Ristevski et al..



Skull pieces of *Paludirex vincenti*. Courtesy Jorgo Ristevski.



Size comparison between *Paludirex vincenti* and a 1.8m (6ft) tall human. Illustration courtesy Jorgo Ristevski.

The Darling Downs today, where paludirex used to be encountered. This has since almost certainly become a more arid environment. Photo courtesy Janelle Lugge/www.shutterstock.com

Further information

Jorgo Ristevski, Adam M. Yates, Gilbert J. Price, Ralph E. Molnar, Vera Weisbecker, Steven W. Salisbury. **Australia's prehistoric 'swamp king': revision of the Plio-Pleistocene crocodylian genus *Pallimnarchus* de Vis, 1886.** *PeerJ*, 2020; 8: e10466 DOI: 10.7717/peerj.10466

HOW FLYING REPTILES EVOLVED

Artwork courtesy Warpaint/www.shutterstock.com

Pterosaurs were the earliest vertebrates to develop the ability to fly, dominating the skies for 150 million years before they died out along with the dinosaurs some 66 million years ago. However, key details of their evolutionary origin and how they gained their ability to fly have remained a mystery; one that palaeontologists have been trying to crack for the past 200 years.

In order to learn more about their evolution and fill in a few gaps in the fossil record, their closest relatives had to be identified. Now, with the help of newly discovered skulls and skeletons that have been unearthed in North America, Brazil, Argentina and Madagascar over recent years, Virginia Tech researchers Sterling Nesbitt and Michelle Stocker from the Department of Geosciences in the College of Science have demonstrated that a group of 'dinosaur precursors' called lagerpetids are in fact the closest relatives of pterosaurs.

A major breakthrough

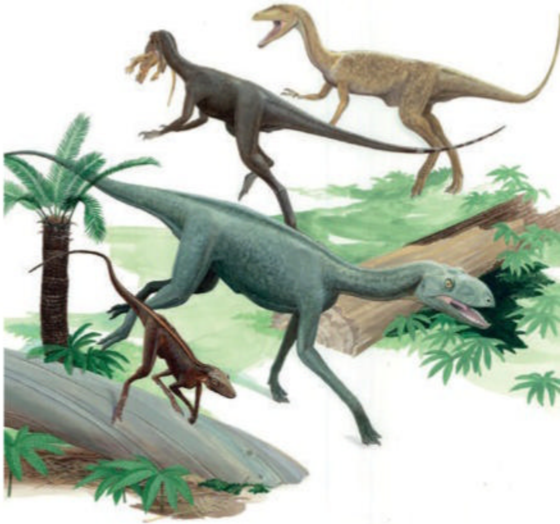
"The question as to where pterosaurs came from is one of the most significant in reptile evolution; we think we now have an answer," says Nesbitt, who is an associate professor of geosciences and an affiliated faculty member of the Fralin Life Sciences Institute and the Global Change Center.

Fossils of *Dromomeron gregorii*, a species of lagerpetid, were first collected during the 1930s and 1940s in the US state of Texas, but they weren't properly identified until 2009. Unique to this excavation was a well-preserved partial skull and braincase, which, after further investigation, revealed that these reptiles had a good sense of equilibrium and were likely to have been agile animals.

After finding more lagerpetid species in South America, palaeontologists were then able to create a pretty good picture of what the lagerpetids were; a group of small, wingless reptiles that lived across the supercontinent Pangea during much of the Triassic Period, from 237 to 210 million years ago.

New finds drive forward our understanding

Over the course of the past 15 years, five research groups from six different countries and three continents have come together to right some wrongs in the evolutionary history of the pterosaur, after the recent discovery of many lagerpetid skulls, forelimbs, and vertebrae from the United States, Brazil,


⮝ Artistic rendering of *Dromomeron* (foreground) and associated dinosaurs and relatives, based on fossils from Ghost Ranch, New Mexico. Illustration courtesy of Donna Braginetz.

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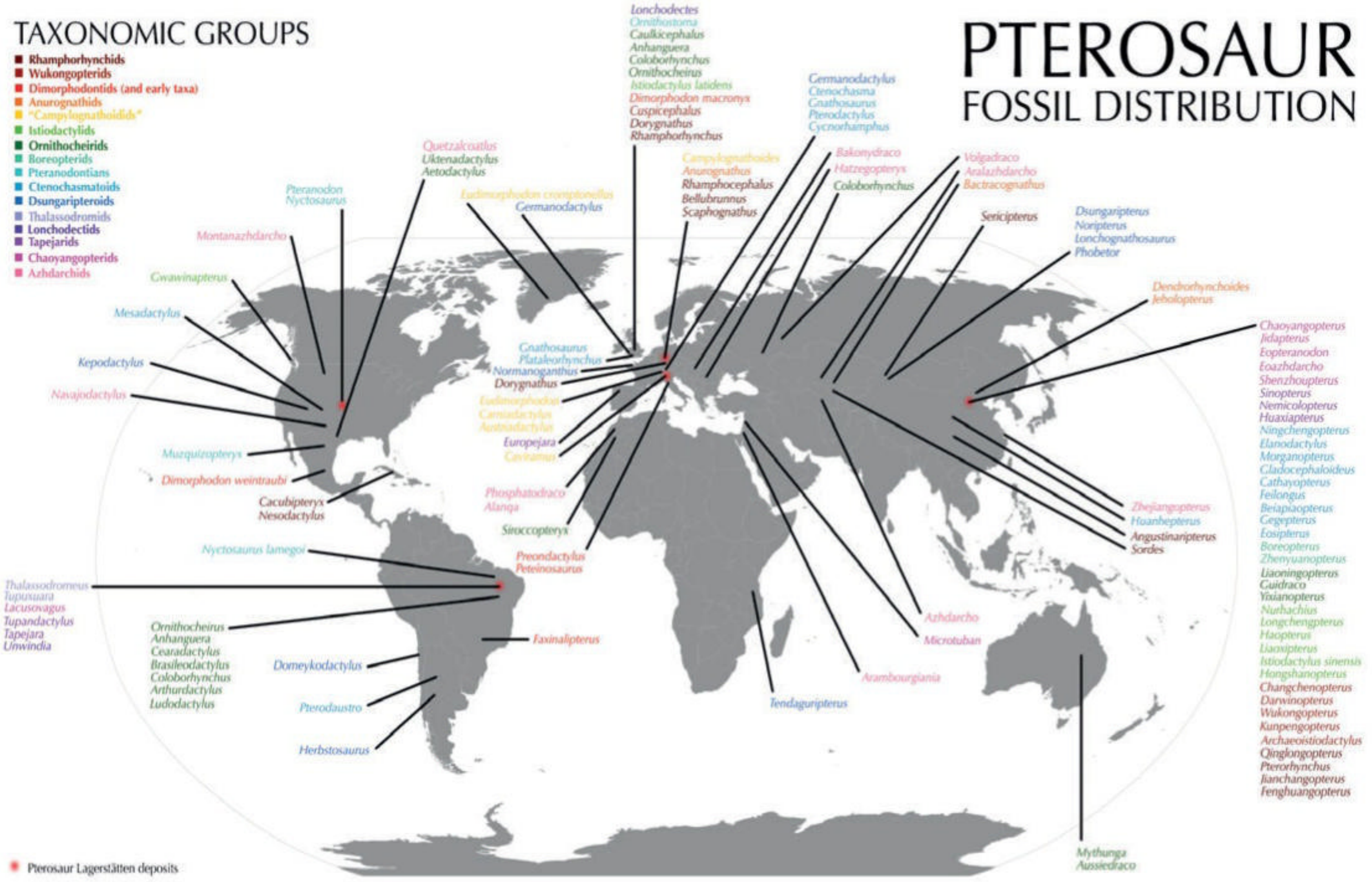

TAXONOMIC GROUPS
Rhamphorhynchids
Wukongopterids
Dimorphodontids (and early taxa)
Anurognathids
"Campylognathoidids"
Istiodactylids
Ornithocheirids
Boreopterids
Pteranodontians
Ctenochasmatoids
Dsungaripteroids
Thalassodromids
Lonchodectids
Tapejarids
Chaoyangopterids
Azhdarchids
PTEROSAUR
FOSSIL DISTRIBUTION
Lonchodectes
Ornithostoma
Caulkicephalus
Anhanguera
Coloborhynchus
Ornithocheirus
Istiodactylus latidens
Dimorphodon macronyx
Cuspicephalus
Dorygnathus
Rhamphorhynchus
Quetzalcoatlus
Uktenadactylus
Aetodactylus
Pteranodon
Nyctosaurus
Eudimorphodon cromptonellus
Germanodactylus
Montanazhdarcho
Gwawinapterus
Mesadactylus
Kepodactylus
Navajodactylus
Muzquizopteryx
Dimorphodon weintraubi
Cacubipteryx
Nesodactylus
Nyctosaurus lamegoi
Thalassodromeus
Tupuxuara
Lacusovagus
Tupandactylus
Tapejara
Unwindia
Ornithocheirus
Anhanguera
Cearadactylus
Brasileodactylus
Coloborhynchus
Arthurdactylus
Ludodactylus
Domeykodactylus
Pterodaustro
Herbstosaurus
Faxinalipterus
Campylognathoides
Anurognathus
Rhamphocephalus
Bellubrunnus
Scaphognathus
Germanodactylus
Ctenochasma
Gnathosaurus
Pterodactylus
Cycnorhamphus
Bakonydraco
Hatzegopteryx
Coloborhynchus
Volgadraco
Aralazhdarcho
Bactracognathus
Sericipterus
Dsungaripterus
Noripterus
Lonchognathosaurus
Phobetor
Dendrorhynchoides
Jeholopterus
Gnathosaurus
Plataleorhynchus
Normanognathus
Dorygnathus
Eudimorphodon
Carniadactylus
Austriadactylus
Europejara
Caviramus
Phosphatodraco
Alanqa
Siroccopteryx
Preondactylus
Peteinosaurus
Azhdarcho
Microtuban
Arambourgiania
Tendaguripterus
Zhejiangopterus
Hoanhepterus
Angustinaripterus
Sordes
Chaoyangopterus
Jidapterus
Eopteranodon
Eoazhdarcho
Shenzhoupterus
Sinopterus
Nemicolopterus
Huaxiapterus
Ningchengopterus
Elanodactylus
Morganopterus
Gladocephaloideus
Cathayopterus
Feilongus
Beiapiaopterus
Gegepterus
Eosipterus
Boreopterus
Zhenyuanopterus
Liaoningopterus
Guidraco
Yixianopterus
Nurhachius
Longchengpterus
Haopterus
Liaoxipterus
Istiodactylus sinensis
Hongshanopterus
Changchenopterus
Darwinopterus
Wukongopterus
Kunpengopterus
Archaeoistiodactylus
Qinglongopterus
Pterorhynchus
Jianchangopterus
Fenghuangopterus
Mythunga
Aussiedraco
Pterosaur Lagerstätten deposits

Argentina, and Madagascar.

What exactly gave palaeontologists the idea to take a look at lagerpetids as the closest relatives of pterosaurs? They have been studying the bones of lagerpetids for quite some time, and noted that the length and shape of their bones were similar to the bones of pterosaurs and dinosaurs. But with the few fossils that they had before, it could only be assumed that lagerpetids were a bit closer to dinosaurs.

The finds that really caused a shift in the family tree were the recently collected lagerpetid skulls and forelimbs, which displayed features that were more similar to those of pterosaurs than dinosaurs. And with the help of new technological advances, researchers found that pterosaurs and lagerpetids share far more similarities than may be immediately obvious.

The key role of technology

Using micro-computed tomographic (µCT) scanning to reconstruct the brains and sensory systems within the recently discovered skulls, palaeontologists were then able to determine that the brains and sensory systems of lagerpetids had many similarities with those of pterosaurs.

"CT data has been revolutionary for palaeontology," says Stocker, who is an assistant professor of vertebrate palaeontology and an affiliated faculty member of the Fralin Life Sciences Institute and the Global Change Center.

"Some of these delicate fossils were collected nearly 80 years ago, and rather than destructively cutting into this first known skull of *Dromomeron*, we were able to use this technology to carefully reconstruct the brain and inner ear anatomy of these small fossils. This is what helped us to determine the early relatives of pterosaurs."

One stark and mystifying finding was that the flightless lagerpetids had already evolved some of the neuroanatomical features that allowed the pterosaurs to fly, which brought forth even more information on the origin of flight. "This study is a result of an international effort applying both traditional and cutting-edge techniques," confirms Martín D. Ezcurra, lead author of the study from the Museo Argentino de Ciencias Naturales in Buenos Aires, Argentina. "It is an example of how modern science and collaboration can shed light on long-standing questions that have puzzled palaeontologists over the course of more than a century."

The fascination surrounding flight

Ultimately, the study will help to bridge the anatomical and evolutionary gaps that exist between pterosaurs and other reptiles. The new evolutionary relationships that have emerged from this study will create a new paradigm, providing a completely new framework for the study of the origin of these reptiles and their flight capabilities.

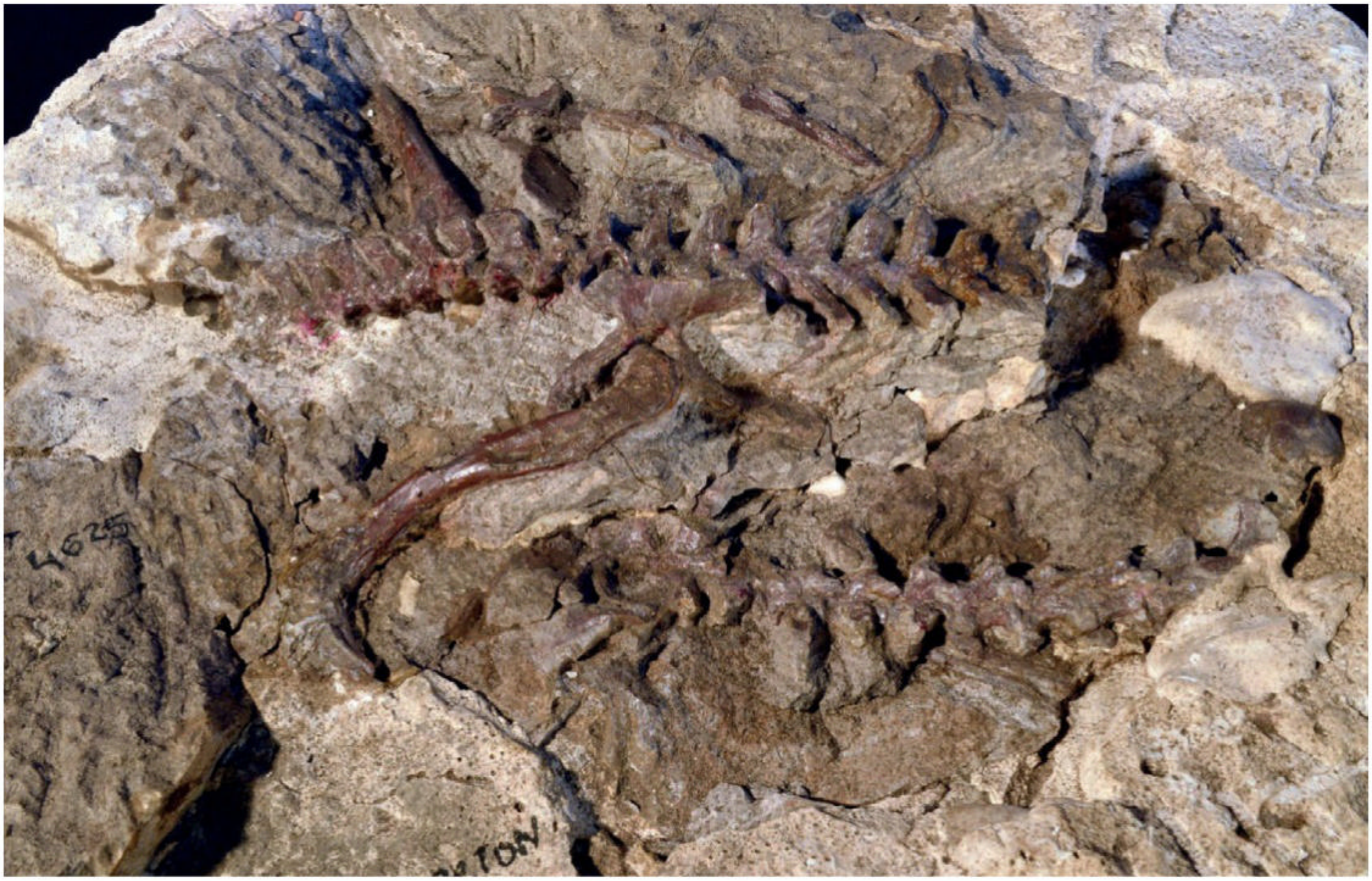
With the little information that palaeontologists possessed about early pterosaurs, they had often attributed extremely fast evolution for the acquisition of their unique body plan. But now that lagerpetids are deemed the precursors of pterosaurs, it is likely that pterosaurs evolved at the same rate as other major reptile groups, thanks to this newly discovered missing link.

"Flight is such a fascinating behaviour, and it has evolved multiple times during Earth's history," says Serjoscha W. Evers, another team member from the University of Fribourg in Switzerland. "Proposing a new hypothesis of their relationships with other extinct animals is a major step forward in understanding the origins of pterosaur flight."

Still more to discover

Some questions still remain, however, in this evolutionary mystery. Now that lagerpetids are the closest relatives of pterosaurs, why are they still lacking some of the key characteristics of pterosaurs, including the most outstanding of those – wings?

"We are still missing lots of information about the earliest pterosaurs, and we still don't



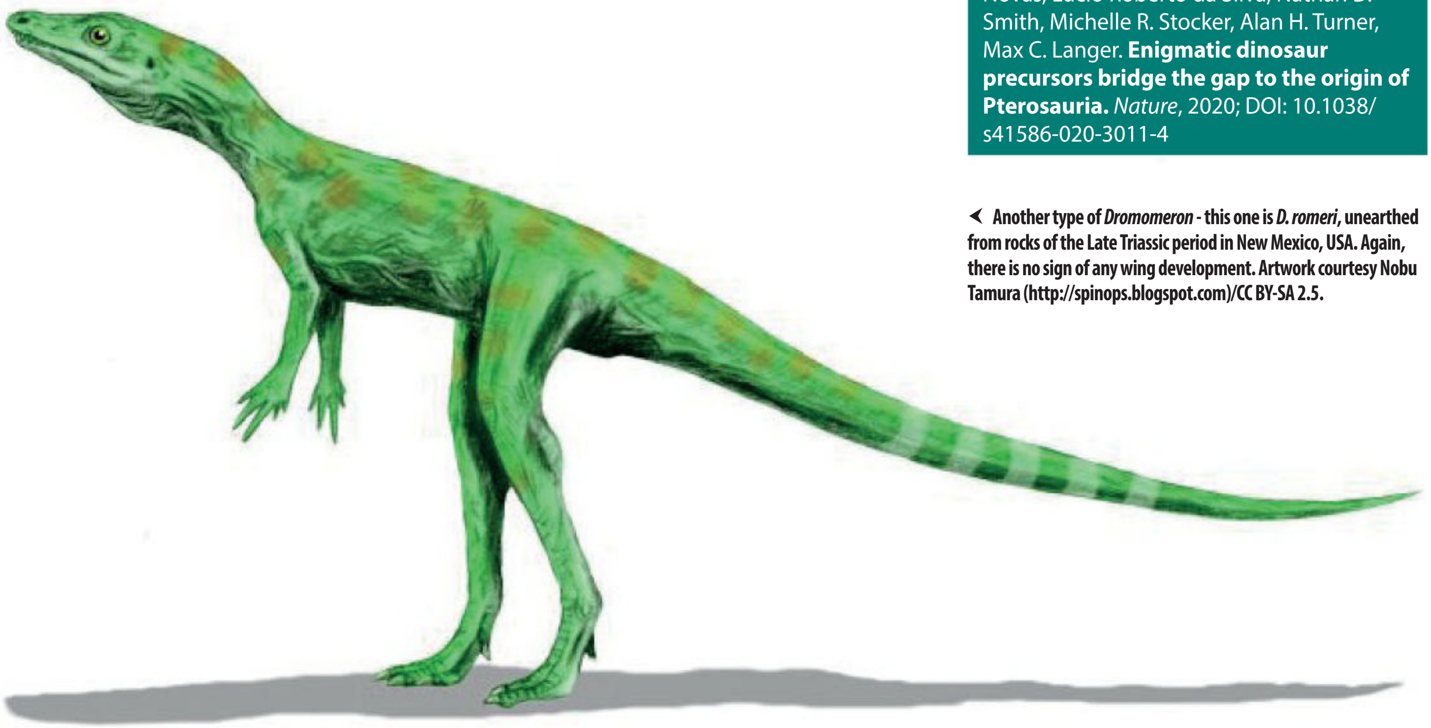
⮝ **A partial skeleton of *Lagerpeton* (comprised of the hips, leg, and vertebrae) from about 235 million years ago, unearthed in Argentina. Further examination of this particular specimen helped to tie features of lagerpetids to pterosaurs.** Photo courtesy of Sterling Nesbitt.

know how their skeletons transformed into an animal that was capable of flight," admits Nesbitt.

Nesbitt, Stocker, and a team of Virginia Tech graduate and undergraduate students will continue to study animals that appeared in the Triassic Period – a period of time in Earth's history when many familiar groups of vertebrates, such as dinosaurs, amphibians and turtles first appeared. Once the covid crisis passes, they plan on going into the field to collect more fossils from the Triassic Period. Hopefully before long, this will give an opportunity to glean more information and put some finishing touches to the original story of flight.

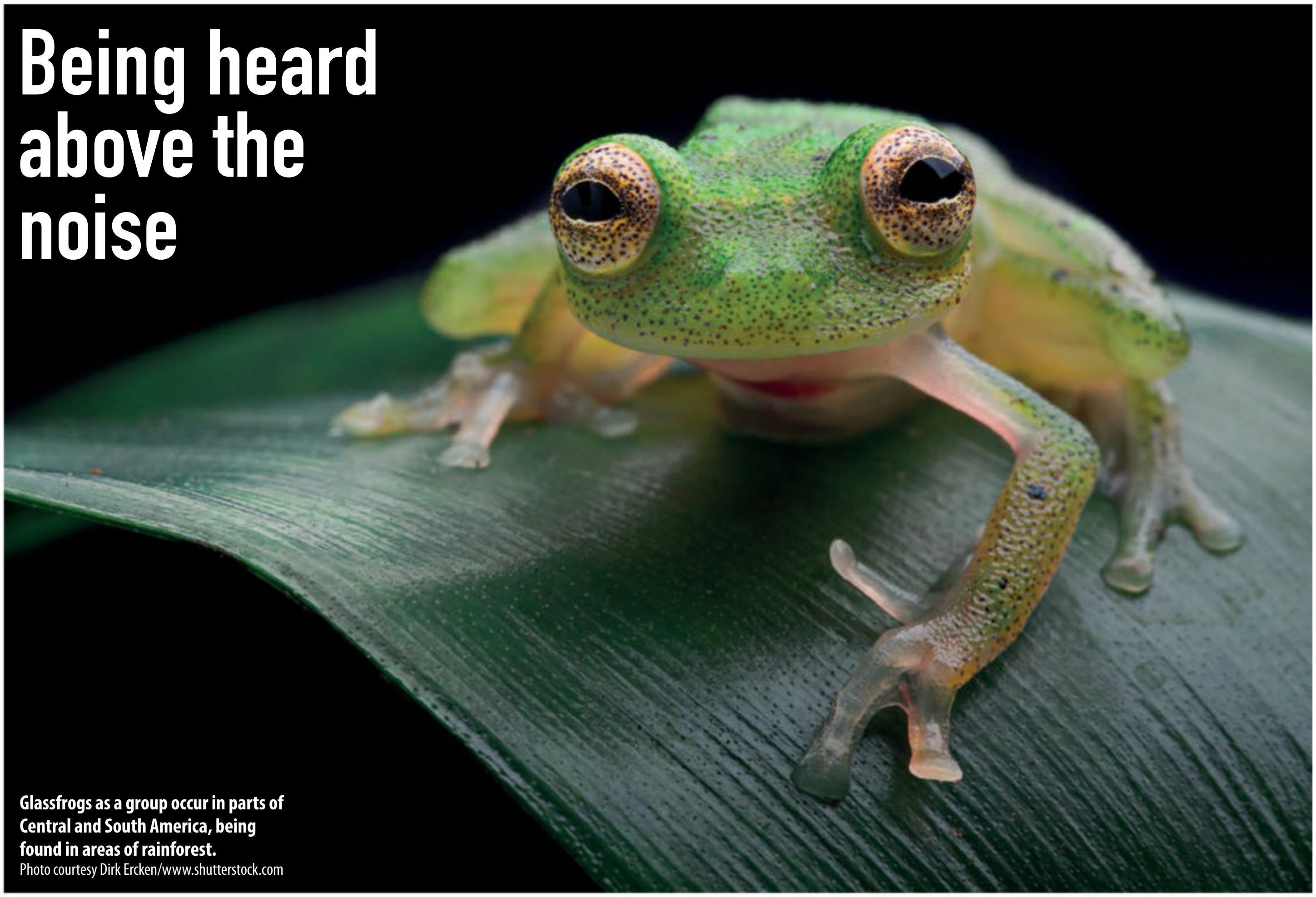
Further information

Martín D. Ezcurra, Sterling J. Nesbitt, Mario Bronzati, Fabio Marco Dalla Vecchia, Federico L. Agnolin, Roger B. J. Benson, Federico Brissón Egli, Sergio F. Cabreira, Serjoscha W. Evers, Adriel R. Gentil, Randall B. Irmis, Agustín G. Martinelli, Fernando E. Novas, Lúcio Roberto da Silva, Nathan D. Smith, Michelle R. Stocker, Alan H. Turner, Max C. Langer. **Enigmatic dinosaur precursors bridge the gap to the origin of Pterosauria.** *Nature*, 2020; DOI: 10.1038/s41586-020-3011-4



⮜ **Another type of *Dromomeron* - this one is *D. romeri*, unearthed from rocks of the Late Triassic period in New Mexico, USA. Again, there is no sign of any wing development. Artwork courtesy Nobu Tamura (http://spinops.blogspot.com)/CC BY-SA 2.5.**

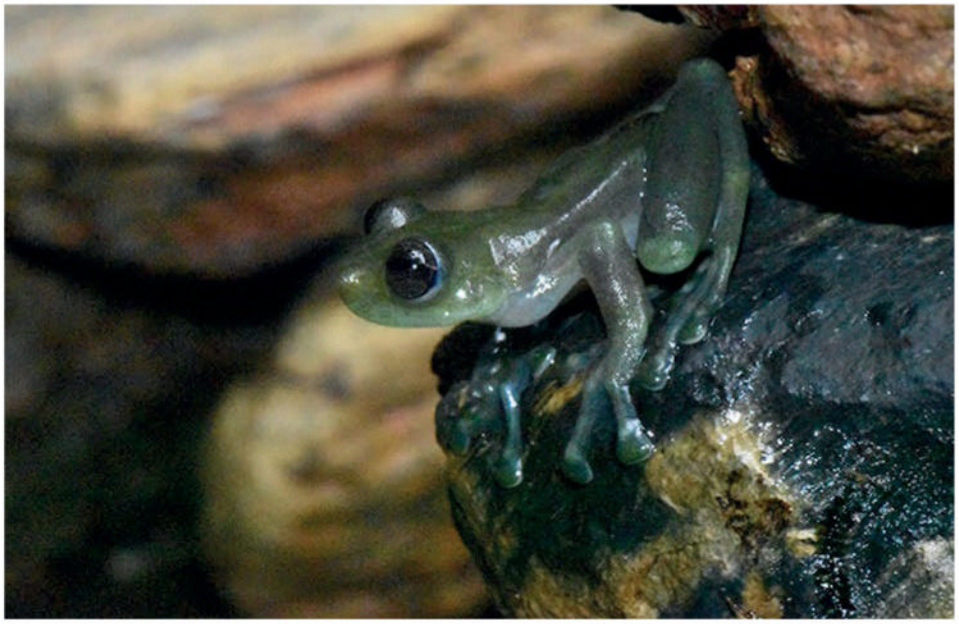
Being heard above the noise



Glassfrogs as a group occur in parts of Central and South America, being found in areas of rainforest.
Photo courtesy Dirk Ercken/www.shutterstock.com

Most frogs emit a characteristic croak to attract the attention of a potential mate. But a few frog species that call near loud streams — where the noise may obscure those crucial love songs — add to their calls by visually showing off with the flap of a hand, a wave of a foot or a bob of the head. Frogs which "dance"in this way near rushing streams have been documented in the rainforests of India, Borneo, Brazil and, now, Ecuador.

Conservation ecologist Rebecca Brunner, from the University of California, Berkeley, has discovered that the glass frog (*Sachatamia orejuela*) can be added to the list of species that make use of visual cues in response to their acoustic environments. This is the first time a member of the glass frog family (Centrolenidae) has been observed using visual communication in this manner.



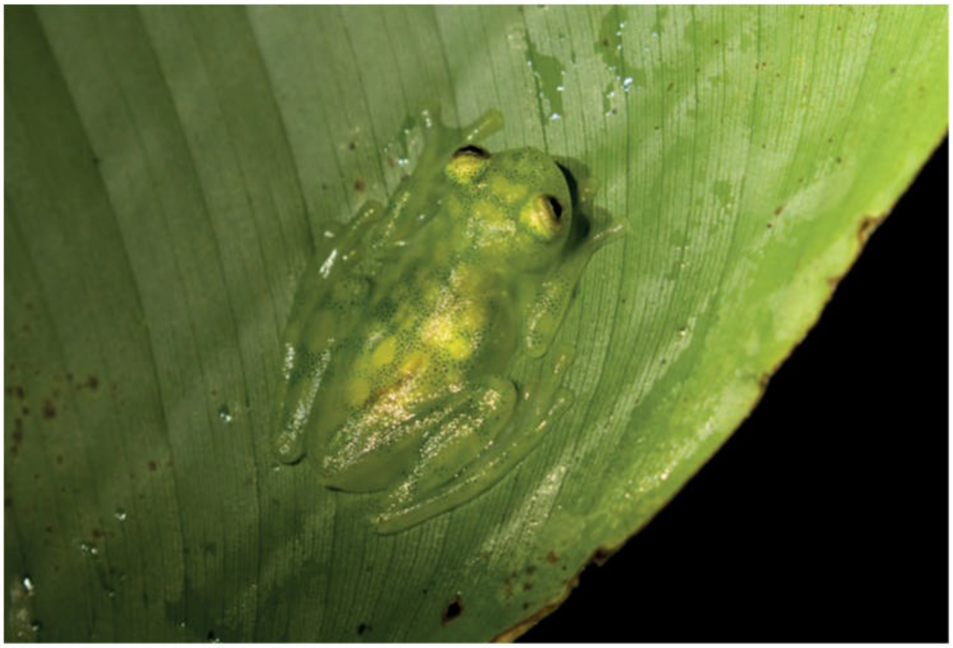
These glass frogs were using their relatively large feet for signalling purposes. Photo courtesy Rachel Brunner.

How this behaviour developed

"A handful of other frog species around the world use visual signalling, in addition to high-pitched calls, to communicate in really loud environments," Brunner says. "What's interesting is that these species are not closely related to each other, which means that these behaviours most likely evolved independently, but in response to similar environments — a concept called convergent evolution."

The glass frogs featured in this study are native to the rainforests of Ecuador and Colombia. They are especially unique because they are seen almost exclusively on rocks and boulders within the spray zones of waterfalls, where their green-grey colour and semi-transparent skin also make them nearly impossible to spot. As a result, little is known about this species' mating and breeding behaviour.

Brunner's colleague captured this photo of her climbing a slippery rock face to film the glass frog. Photo courtesy Rebecca Brunner.



The advantage of the glass frog's semi-transparent body is evident here - it serves to allow it to merge into most backgrounds. Photo courtesy Rob Jansen/www.shutterstock.com

The first sighting

Brunner, who studies the bioacoustics of different ecological environments, was chest-deep in an Ecuadorean rainforest stream recording the call of a this glass frog when she first observed this visual signalling behaviour. As soon as she saw the frog repeatedly raising its front and back legs, Brunner climbed a slippery rock face and balanced on one foot to get video footage to show its behaviour.

"I was already over the moon because I had finally found a calling male after months of searching. Before our publication, there was no official record of this species' call, and basic information like that is really important for conservation," explains Brunner. "But then I saw it start doing these little waves, and I knew that I was observing something even more special."

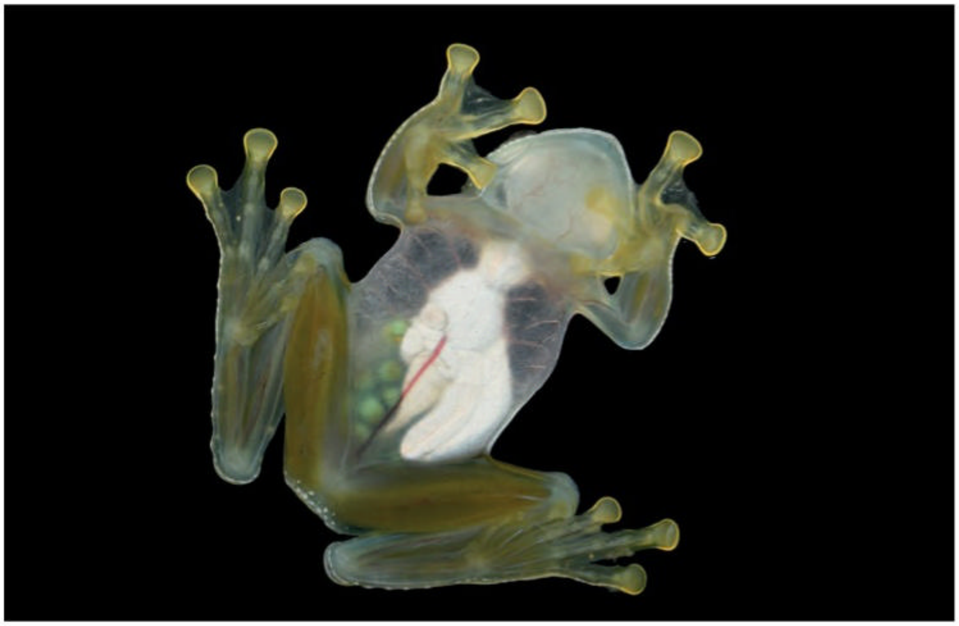
While she filmed, the frog continued to wave its hands and feet, as well as bobbing its head. She also observed another male glass frog located a few metres away performing the same actions.

Other discoveries

"This is a really exhilarating discovery because it's a perfect example of how an environment's soundscape can influence the species that live there. We've also discovered that this glassfrog has an extremely high-pitched call, which helps it to communicate above the lower-pitched white noise of waterfalls. And then to discover that it also waves its hands and feet to increase its chances of being noticed — that's a behaviour I've always loved reading about in textbooks, so it is beyond thrilling to be able to share another amazing example with the world," says Brunner.

Although the COVID-19 pandemic has put a pause on Brunner's fieldwork, she hopes to return to Ecuador soon to continue her research, which links bioacoustics and conservation. "One of the best things about fieldwork is that nature is always full of surprises — you never know what discoveries you may happen upon," Brunner adds.

"I hope our findings can serve as a reminder that we share this planet with incredible biodiversity. Conserving ecosystems that support species like glass frogs is important not only for our well-being, but also for our sense of wonder."



Glass frogs are so-called because of their semi-transparent skin. Note the green eggs within the body of this individual. Photo courtesy petrdd/www.shutterstock.com

Further information

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Magnetic switch defends against snake venom

Certain snakes have evolved a unique genetic trick to avoid being eaten by venomous snakes, according to University of Queensland research.

Associate Professor Bryan Fry from UQ's Toxin Evolution Lab in Australia explains the technique works in a manner similar to the way that two sides of a magnet repel each other.

"The target of snake venom neurotoxins is a strongly negatively charged nerve receptor," Dr Fry says. "This has caused neurotoxins to evolve with positively charged surfaces, thereby guiding them to the neurological target to produce paralysis.

"As a result, some snakes have evolved a means to replace a negatively charged amino acid on their receptor with a positively charged one, meaning that the neurotoxin is repelled as a result. It's an incredibly inventive genetic mutation and it's been completely missed until now. We've shown this trait has evolved at least 10 times in different species of snake."

Which species?

The researchers found that the Burmese python (*Python molurus*) – a slow-moving terrestrial species vulnerable to predation by cobras – is extremely neurotoxin resistant. Similarly, the South African mole snake (*Pseudaspis cana*), another slow-moving snake vulnerable to cobras, shares this trait with Burmese pythons. Dr Fry explains "But Asian pythons which live in trees as babies, and Australian pythons which do not live alongside neurotoxic snake-eating snakes, have not acquired this resistance.

"We've long known that some animals – like mongooses – are resistant to snake venom through a mutation that physically blocks neurotoxins by having a branch-like structure sticking out of the receptor, but this is the first time this magnet-like effect has been observed. It has also evolved on at least two occasions in venomous snakes, allowing them to be resistant to their own neurotoxins."

Associate Professor Bryan Fry says this is one of the advances in knowledge directly attributable to the opening of the Australian Biomolecular Interaction Facility (ABIF). Photo courtesy University of Queensland.

The South African mole snake is also protected against neurotoxic venom as the result of a difference in charge at the site where the nerve toxin would normally bind. Photo courtesy Dewald Kirsten/www.shutterstock.com

In Asia, the Burmese python is well-defended against deadly cobra venom, thanks to a newly-recognised genetic mutation. Photo courtesy Heiko Kiera/www.shutterstock.com

New facilities

The discovery was made after the establishment of UQ's new $2 million biomolecular interaction facility, known as the Australian Biomolecular Interaction Facility (ABIF). "There's some incredible technology at the ABIF allowing us to screen thousands of samples a day," says Dr Fry. "That facility means we can do the kinds of tests that would have just been science fiction before: they would have been completely impossible."

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Venom serves a defensive purpose

A study of spitting cobras (*Naja and Hemachatus* species) reveals how a combination of venom components have evolved to create an instantly painful venom, not once, but on three separate occasions. This is the first clear example of snake venom evolving for defence, and provides a remarkable example of convergent evolution, or how natural selection can cause the same solution to a problem to evolve multiple times.

Contrary to the theory that venoms are adapted primarily to enable snakes to kill prey, the venom produced by spitting cobras causes instant pain, and has a delivery system which enables the snake to spray the venom as far as 2.5m (8.2ft) towards the eyes of anything which comes too close, suggesting that it serves as a defence mechanism, rather than as hunting weaponry.

Spitting cobras are able to spray their venom with precision, by adjusting the position of their head.
Photo courtesy Eugene Troskie/www.shutterstock.com

Evolutionary repeats

Dr Wolfgang Wüster, of Bangor University's School of Natural Sciences, co-investigator on this international research project, which is led by Dr Taline Kazandjian and Professor Nick Casewell at the Liverpool School of Tropical Medicine, explains: "Here's a further strong piece of evidence to illustrate that similar evolutionary challenges often generate the same solutions. Even though we studied three different cobra groups, which evolved in different locations and at different evolutionary time periods, each evolved the same defensive mechanisms in the face of a threat."

All cobras have venom components that cause tissue destruction, called cytotoxins. But in spitting cobras, adding another group of toxins, known as phospholipases A2, has created a synergistic effect, resulting in an instantly painful venom, which can rapidly deter and even blind an aggressor.

Understanding to what extent evolution is unpredictable, almost random, or predictable, is a major question in biology. This is a remarkable example of the same problem leading to the evolution of the same solution several times in succession – that is, predictable evolution.

Could early humans be involved?

Intriguingly, by working back through evolutionary lineages, the team also found that the changes occurred in the three different geographic locations around the same time that early humans appeared in the fossil record in those areas.

Dr Wüster adds: "Many primates attack snakes with sticks and stones. The arrival of bipedal hominids, with both hands free, may have been just the kind of selection pressure that favoured long-distance defence through spitting and a specially adapted defensive venom.

The idea that early humans, millions of years ago, may have caused the evolution of spitting in cobras emphasises how our origins were very much intertwined with the wider ecosystems of Africa and Asia at that stage."

Spitting cobras can seemingly use their venom to defend themselves from some distance away, rather than just relying on it to overpower prey. A Mozambique spitting cobra (*Naja mossambica*) is seen here.
Photo courtesy Stu Porter/www.shutterstock.com

The venom produced by spitting cobras contains a specific component that can blind an aggressor.
Photo © Wolfgang Wüster from eSwatini.jpg.

Today, spitting cobras may use their venom to defend themselves from would-be mammalian predators such as mongooses. Photo courtesy Stacey Ann Alberts/www.shutterstock.com

Further information

T. D. Kazandjian, D. Petras, S. D. Robinson, J. Van Thiel, H. W. Greene, K. Arbuckle, A. Barlow, D. A. Carter, R. M. Wouters, G. Whiteley, S. C. Wagstaff, A. S. Arias, L.-O. Albulescu, A. Plettenberg Laing, C. Hall, A. Heap, S. Penrhyn-Lowe, C. V. Mccabe, S. Ainsworth, R. R. Da Silva, P. C. Dorrestein, M. K. Richardson, J. M. Gutiérrez, J. J. Calvete, R. A. Harrison, I. Vetter, E. A. B. Undheim, W. Wüster, N. R. Casewell. **Convergent evolution of pain-inducing defensive venom components in spitting cobras.** *Science*, 2021 DOI: 10.1126/science.abb9303

Helping the survival of young crocodilians

⮝ **A young spectacled caiman looks out cautiously above the water surface.** Photo courtesy Michael Meshcheryakov/www.shutterstock.com

The findings of a new study examining the behaviours of alligator and caiman hatchlings have enhanced our understanding of how we can conserve, and increase, the population of endangered crocodilian species.

Once they are adults, there are key differences between the American alligator (*Alligator alligator*) and the closely related spectacled caiman (*Caiman crocodilus*). However, at the time of hatching, both species are relatively small and might be expected to show similar behaviours in order to avoid being eaten by almost any carnivore around.

Curious alligators and withdrawn caimans

Now, researchers at the Universities of Lincoln (UK) and Vienna have conducted comparative studies between the hatchlings of these crocodilians and discovered that alligators are more active and likely to explore their surroundings, compared with caimans. The research, carried out at Crocodiles of the World (https://www.crocodilesoftheworld.co.uk), which is the only zoological collection in the UK specialising in keeping crocodilians, put American alligator and spectacled caiman hatchlings in unfamiliar environments and

⮝ **Young alligators are more active and curious than spectacled caimans, based on this study.** Photo courtesy Eva Pruchova/www.shutterstock.com

Spectacled caimans grow to a smaller size than American alligators. Instinctive caution when young may protect them from a higher rate of predation.
Photo courtesy Erni/ww.shutterstock.com

presented them with unknown objects.

The team found that the alligators moved around much more than the caimans in all conditions and approached the unknown objects closer than the caimans. This behaviour may be linked with the strength of maternal protection that the hatchlings receive early in life.

Conservation implications

Anna Wilkinson, who is Professor of Animal Cognition at the University of Lincoln, says: "The findings of this study are exciting as they have important conservation implications. Several crocodilian species are endangered in the wild and one way to increase their population size is to release captive-bred juveniles into the wild. If the endangered species is a large crocodilian and at the top of the food chain, the juveniles should be allowed to grow to a larger size prior to release as they might have a lower natural predator avoidance.

"On the flip side, spectacled caimans are an invasive species in the natural range of other crocodilians, including the American alligator, and one reason for their success could be a higher survival rate of their hatchlings because of their stronger tendency to avoid predators."

Co-researcher Dr Stephan Reber, says: "During our research, the movements of the animals were coded automatically using a colour tracking software developed specifically for this study.

"We used automatic coding because it allows us to catch even very small differences in behaviour. The observed behavioural tendencies of the hatchlings are very reminiscent of those of adults. Adult American alligators are rather self-assured and confident, while adult spectacled caimans are, in comparison, a bit jumpier and more easily spooked."

⮝ American alligators are well-placed to protect their offspring, compared with caimans.
Photo courtesy Images by Claudia Dabniels/www.shutterstock.com

Why the difference?

Hatchlings of the two species are probably equally susceptible to predators due to their similar size, but the researchers suggest that the different behaviour observed in the hatchlings is a reflection of the strength of maternal protection. All crocodilians are guarded by a parent (usually the mother) for a considerable amount of time after hatching. The strength of that protection depends on the adult size of the parents.

Dr Reber explains: "American alligator mothers have no natural enemies in their habitat and can protect their hatchlings effectively against any predator. On the other hand, adult spectacled caimans have many predators, including cougars, jaguars and giant snakes. Therefore, American alligator hatchlings can afford to be more explorative under their mother's watchful eye, while spectacled caimans probably behave more inconspicuously to avoid attracting attention even if they are guarded."

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How frogs can fight off fungus

The Costa Rican rainforest is home to certain amphibians that display natural resistance to chytrid.
Photo courtesy LOUIS-MICHEL DESERT/www.shutterstock.com

Scientists in Costa Rica have found that some bacteria on the skin of amphibians prevent growth of the fungus responsible for what has been dubbed 'the amphibian apocalypse'. This new research identified a number of bacteria which could prevent growth of the fungus *Batrachochytrium dendrobatidis* (Bd), that is responsible for the infection known as chytridiomycosis, often abbreviated simply to chytrid.

Devastating impacts

One particularly dangerous strain of the fungus, called BdGPL-2, is responsible for mass amphibian die-offs around the world. The fungus infects the skin of amphibians, breaking down the cells. As amphibians breathe and regulate water through their skin, this means infection is typically deadly. It is believed that almost 700 species of amphibian are vulnerable to the fungus, and Bd has already led to the extinction of 90 amphibian species.

In order to investigate why some amphibian populations in Costa Rica were more resilient to Bd that others, a research group led by Dr Adrian Pinto, Professor at the University of Costa Rica sampled the circulating strains of Bd and the microbes present on the skin of amphibians at different sites.

Mérida
Progreso
Campeche
Villahermosa
YUCATAN
Chetumal
Belize City
BELIZE
Belmopan
Tuxtla Gutierrez
Cayman Islands (U.K.)
Montego Bay
JAMAICA
Golfo de Honduras
Puerto Cortés
La Ceiba
San Pedro Sula
GUATEMALA
HONDURAS
Tegucigalpa
Tapachula
Quezaltenango
Guatemala
Santa Ana
San Salvador
EL SALVADOR
San Miguel
León
Managua
NICARAGUA
Matagalpa
Bluefields
Lago de Nicaragua
Rivas
San José
Limón
Puntarenas
COSTA RICA
Chirripó 3820
David
Santiago
PANAMA
Panamá
Colón
Golfo de los Mosquitos
Golfo de Panamá
ISLA DE PROVIDENCIA (Colombia)
ISLA DE SAN ANDRÉS
Barranquilla
Cartagena
Golfo de Darien
ISLA DEL COCO (Costa Rica)
ISLA DE MALPELO (Colombia)
COLOMBIA
GALAPAGOS ISLANDS (Ecuador)

Costa Rica lies to the north of Panama.
Map courtesy Poparti c/www.shutterstock.com

The research group collected wild amphibians from areas of Costa Rica which had a history of Bd outbreaks. "Bd has previously been widely detected in Costa Rica, but this is the first study to isolate and compare the characteristics of different

⮝ **The rainforest in Costa Rica displays incredible biodiversity - but amphibian populations have plummeted because of chytrid infections.** Photo courtesy Dinael Oropeza/www.shutterstock.com

isolates," says Dr Pinto. "Our work showed that the circulating strains of the pathogenic fungus here belong to a highly virulent global strain known as BdGPL-2."

Individual variations are significant

Nevertheless, the team found that the bacteria on the skin of some surviving amphibians prevented growth of the fungus in the lab. "Amphibian species that survived the decline harbour bacteria on their skin capable of inhibiting the growth of the pathogen. However, this inhibitory capacity varies according to which strain of the fungus is being tested," Dr Pinto explains. "These findings suggest that locally adapted skin bacteria may offer protection from the disease."

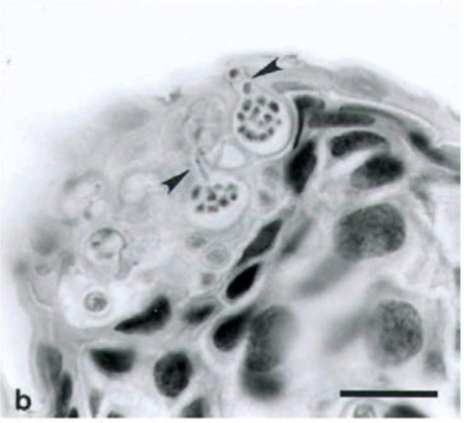
Although the researchers expected to see the highly virulent strain BdGPL-2 in Costa Rica, they did not expect to see so much variation in circulating strains. "We were surprised by the variations among the harmful fungal isolates, including their different responses to the antagonistic bacteria," said Dr Pinto. "Local pathogen adaptations must be considered when designing mitigation strategies for this disease."

Dr Pinto hopes to combine their findings with other disease control strategies to protect amphibian populations from decimation by Bd in the future. "We will continue to study the ability of skin bacteria to protect amphibians against disease, as another tool to combat this plague, alongside the creation of climate shelters and fostering the amphibians' own immune system," he confirms.

A country under threat

Costa Rica is one of the countries that suffered a dramatic loss of amphibian species between the 1980 and 1990. In Costa Rica, there are currently 64 species of amphibians in some risk category according to the International Union for the Conservation of Nature.

The variable harlequin frog has suffered severely from chytrid fungus infection, as have other members of its genus. Photo courtesy Brian.gratwicke/Wikipedia/CC BY-SA 3.0.



⮝ **Chytridiomycosis in the skin of a variable harlequin frog, as arrowed.** Image courtesy Peter Daszak, Lee Berger, Andrew A. Cunningham, Alex D. Hyatt, D. Earl Green, and Rick Speare/PD.

Species classified as critically endangered include the Holdridge's toad (*Incilius holdridgei*), a native species found only in the mountain ranges of the central region; the variable harlequin frog (*Atelopus varius*), a river species known to be very sensitive to Bd, and several species of river tree frogs of the genus *Isthmohyla* that live in cold currents in high areas, reflecting a habitat where Bd proliferates successfully.

Amphibians are one of the most diverse groups in the tropics and represent crucial links in food webs. Protecting them helps to keep ecosystems healthy, since biological diversity is the basis for resilient forests. Their presence has the benefits of helping control insect pests and preventing the spread of zoonotic infections which can be transmitted to people.

Further information

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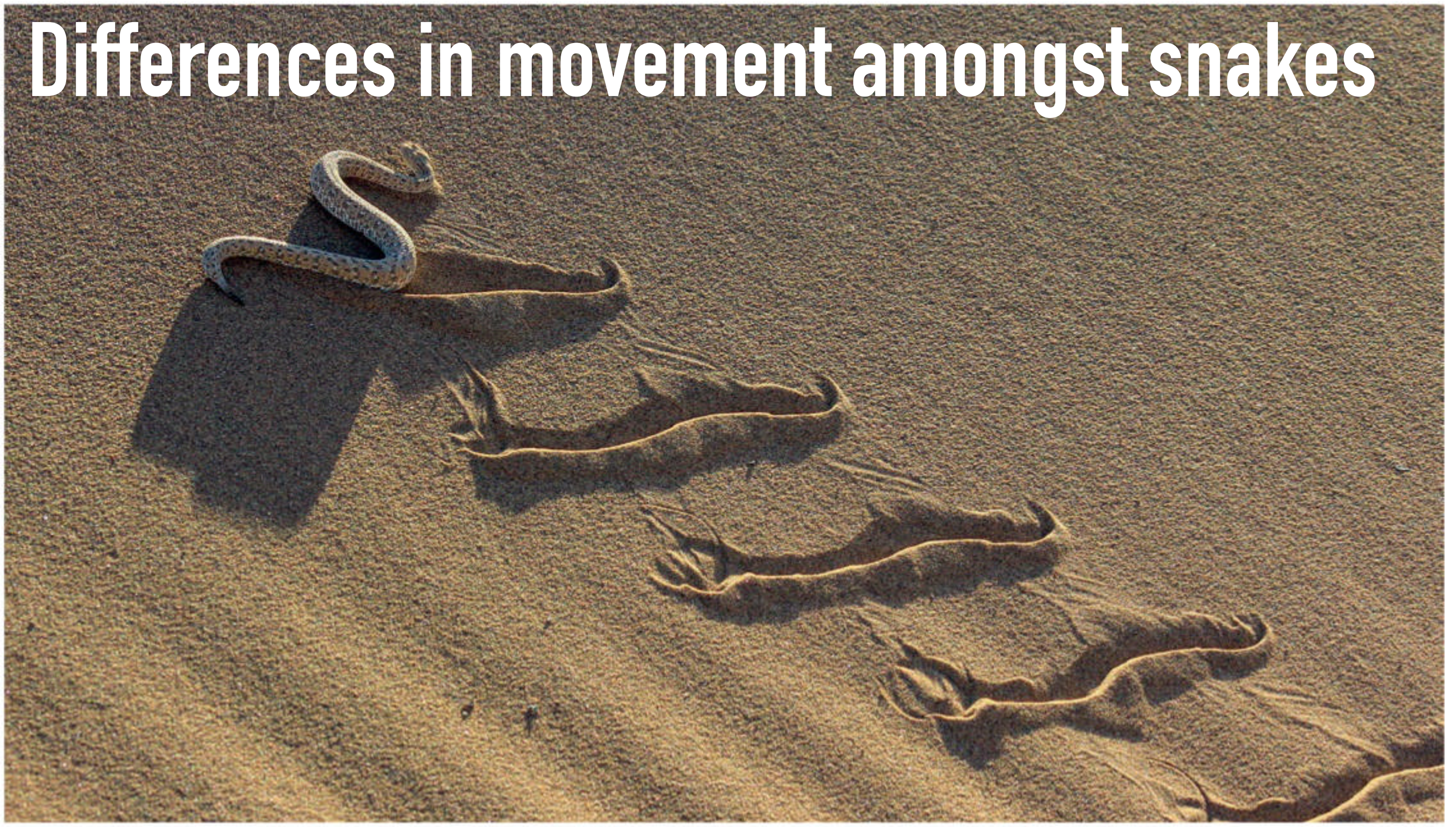
Differences in movement amongst snakes



⮝ A sidewinder (*Bitis peringueyi*) in the Namib desert in southwestern Africa, making tracks climbing a dune in late afternoon light. Note the distinctive pattern left in the sand. Photo courtesy Chantelle Bosch/www.shutterstock.com

Most snakes move by bending their bodies into S-shapes and slithering forward headfirst. A few species, however — found in the deserts of North America, Africa and the Middle East — have a different, more unusual way of getting around. Known as sidewinders, these snakes lead with their mid-sections instead of their heads, slinking sideways across loose sand.

Scientists have recently taken a microscopic look at the skin of sidewinders to see if it plays a role in their unique method of movement. They discovered that sidewinders' bellies are studded with tiny pits and have few, if any, of the tiny spikes found on the underside of other snakes.

"The specialised locomotion of sidewinders evolved independently in different species in different parts of the world, suggesting that sidewinding is a good solution to a problem," says Jennifer Rieser, assistant professor of physics at Emory University in the US city of Atlanta. "Understanding how and why this example of convergent evolution works may allow us to adapt it for our own needs, such as building robots that can move in challenging environments."

➤ A Saharan horned viper (*Cerastes cerastes*) is a species of sidewinder native to the deserts of northern Africa and parts of the Arabian peninsula. Sidewinders in this region have had longer to adapt to a desert environment.
Photo courtesy Mark_Kostich/www.shutterstock.com

Shaping robots

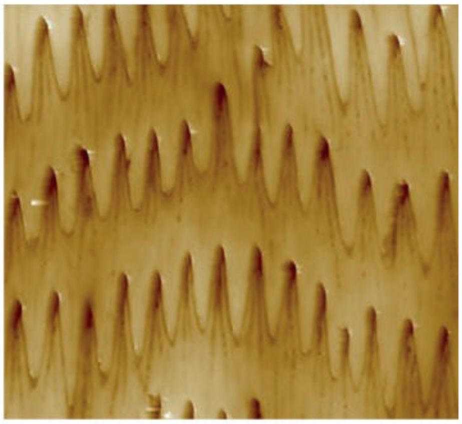
Rieser's research interests bring together the physics of soft matter — flowable materials like sand — and biology. She studies how animals' body surfaces interact with the flowable materials in their environments to get around. Insights from her research may lead to improvements in human technology.

Snakes, and other limbless creatures that can move easily are particularly interesting to Rieser. "Even though snakes have a relatively simple body plan, they are able to navigate a variety of habitats successfully," she says. Their long, flexible bodies are inspiring work on "snake-based" robots for everything from surgical procedures to search-and-rescue missions in collapsed buildings.

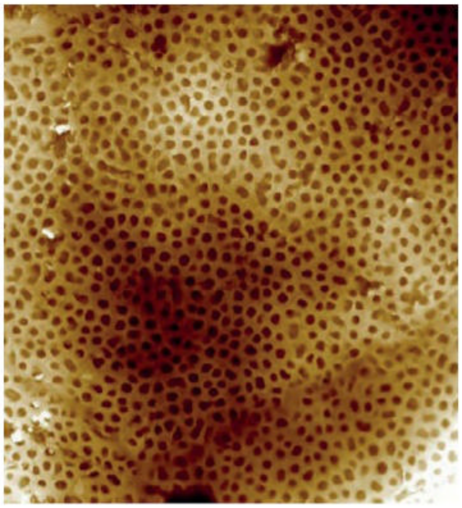
Rieser and her team had previously found that robots designed to move in serpentine ways could help them to avoid catastrophe when they collided with objects in their path. This new research with sidewinders offered her a chance to investigate further as to how nature has evolved ways to move across loose sand and other soft matter.

Interaction between the surface and snake

Most snakes tend to keep their bellies largely in contact with the ground as they slide forward, bending their bodies from their heads to their



▲ The Mexican lance-headed rattlesnake (*Crotalus polystictus*) moves by slithering forward. A micrograph from the study, above, of the skin of its belly reveals spikes that are normally invisible to the eye. The micrograph image shows a surface 20 microns wide, equivalent to about a third of the width of a human hair. Photo courtesy Tai-De Li.



▲ A micrograph of the skin of the Saharan sand viper (*Cerastes vipera*), a sidewinder, reveals that its belly is studded with pits instead of spikes. Image again shows a surface about 20 microns wide. Photo courtesy Tai-De Li.

▲ The sidewinder's mode of locomotion may help it to move more effectively on sandy slopes.
Photo courtesy Piece of peace/www.shutterstock.com

tails. A sidewinder, however, lifts its mid-section off the ground, shifting it in a sideways direction.

Previous studies have suggested that sidewinding may allow a snake to move better on sandy slopes. "The thought is that sidewinders spread out the forces that their bodies impart to the ground as they move, so that they don't cause a sand dune to avalanche when they move across it," Rieser explains.

As part of this new research, Rieser and her colleagues investigated whether sidewinders' skin might also play a role in their unique style of movement.

They focused on three species of sidewinders, all of them vipers in residence at zoos: the sidewinder rattlesnake (*Crotalus cerastes*), found in the deserts of the southwestern USA and northern Mexico; the Saharan horned viper (*Cerastes cerastes*) and the Saharan sand viper (*Cerastes vipera*), both originating from the deserts of north Africa.

What scanning of the skin revealed

Skins shed from the sidewinders were collected and scanned with atomic force microscopy, a technique that provides resolution at the atomic level, at fractions of a nanometer, which reveals incredible detail. For comparison, the team also scanned snake skins shed by non-sidewinders.

As expected, the microscopy revealed tiny, head-to-tail pointing spikes on the skin of the non-sidewinders. Previous research had identified these micro spikes on a variety of other slithering snakes.

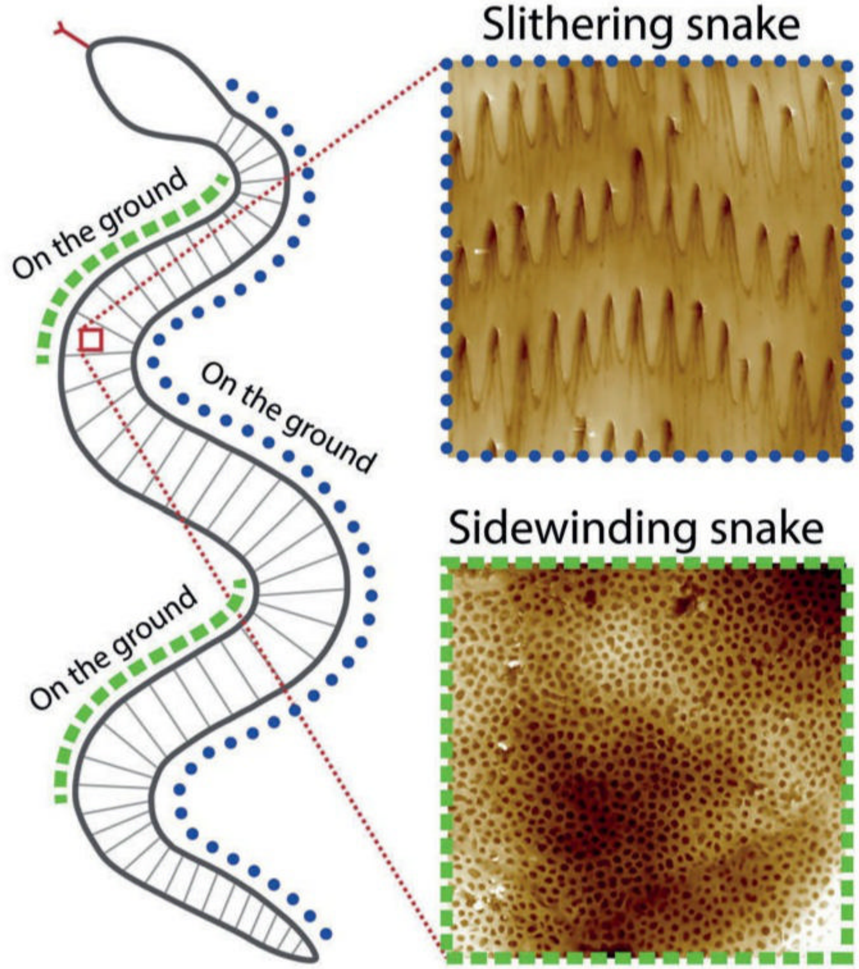
What was new, however, is that the skin of sidewinders is different. The two African sidewinders had micro pits on their bellies and no spikes. The skin of the sidewinder rattlesnake was also studded with tiny pits, along with a few, much smaller spikes — although far fewer spikes than those of the slithering snakes.

The researchers created a mathematical model to test how these different structures affect frictional interactions with a surface. The model showed that head-to-tail pointing spikes enhance the speed and distance of forward undulation but are detrimental to sidewinding.

"Think about it like the ridges on corduroy material," Rieser explains. "When you run your

The sidewinder rattlesnake (*Crotalus cerastes*), found in the southwestern United States and northwestern Mexico, has had less time evolutionarily to adapt to a sandy environment, since American sandy deserts are much younger than those in Africa.
Photo courtesy Mark_Kostich/www.shutterstock.com

⮝ Sidewinders can burrow effectively into the sand, concealing their presence here, and are very effective ambush predators. Photo courtesy Chantelle Bosch/www.shutterstock.com



⮝ Graphic shows how snakes that slither forward and sidewinders use their bodies differently for locomotion, along with microscopic differences in the skin of their bellies. Artwork courtesy Jennifer Rieser.

fingers along corduroy in the same direction as the ridges there is less friction than when you slide your fingers across the ridges."

The model also showed that the uniform, non-directional structure of the round pits enhanced sidewinding, but was not as efficient as spikes for forward undulation.

The significance of time?

The research provides snapshots at different points in time of convergent evolution — when different species independently evolve similar traits as a result of having to adapt to similar environments. Rieser notes that American sandy deserts are much younger than those in Africa. The Mojave of North America accumulated sand only about 20,000 years ago while sandy conditions appeared in the Sahara region at least seven million years ago.

"That may explain why the sidewinder rattlesnake still has a few micro spikes left on its belly," she says. "It has not had as much time to evolve specialised locomotion for a sandy environment as the two African species that have already lost all of their spikes."

Engineers may also want to adapt their robot designs accordingly, Rieser adds. "It depends what type of surface you need a robot to move on," she says. "You may want to consider designing the robot's surface to have a particular texture to enhance its movement over a specific surface."

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REVEALED: THE DEEPEST-NESTER OF ALL VERTEBRATES

Ten years of research led by the University of South Florida (USF) has revealed that a monitor lizard should be regarded as an 'ecosystem engineer', which is a description rarely given to a reptiles. Tortoises and sea turtles are the only reptiles considered to be ecosystem engineers. This is a term used to describe organisms that have a great impact on their environment based on their ability to create, modify, maintain or destroy a habitat.

Sean Doody, assistant professor and graduate director of integrative biology at the USF St. Petersburg campus, discovered that while a related species is considered invasive in the USA, small animal communities in Australia rely on the monitor lizards' burrow system, called a warren, using it as a habitat where they can forage for food and nest.

Doody and his Australian collaborators investigated the nesting biology of the yellow-spotted or Argus monitor lizard (*Varanus panoptes*), which can measure 1.5m (5ft) and its smaller relative, known as the sand or Gould's monitor (*Varanus gouldii*). The team had recently discovered that these lizards are unique in that they lay their eggs as far down as 4m (13ft) underground, which makes them easily the deepest vertebrate nests on earth.

Home to many

The monitors loosen the soil, creating warm, moist conditions, which are ideal for laying eggs and trapping viable seeds and fruits. But now, the researchers have discovered that the burrows hosted a wide range of animals, including reptiles, frogs, insects and even marsupial mammals. The team found 747 individual species comprising 28 different types of vertebrate.

The timing of the research revealed clues as to why certain species utilised the warrens. For example, throughout the winter dry season, the researchers found hibernating frogs using the burrows to maintain their body moisture. During one excavation, Doody and his team discovered 418 individual frogs in a single warren.

An invasive threat

"The finding is significant as it shows that nesting warrens provide critical shelter and other resources for the small animal community," Doody says. "The invasive cane toad is decimating the monitor lizards in some areas, meaning that these nesting warrens, which are re-used year after year, will disappear. This can impact the relative number of predators and prey, which can then have unexpected consequences for the ecosystem, such as an overabundance of one species at the cost of another, which in other systems has threatened species with local extinction."

⮝ A yellow-spotted monitor. Its powerful claws help it to dig very effectively. Photo courtesy Ken Griffiths/www.shutterstock.com

⮝ The gopher tortoise (*Gopherus polyphemus*) is another example of the few reptiles that are considered as ecosystem engineers, because of their impact on the landscape. These tortoises dig long burrows which can be up to 10m (33ft) long and are also home to a large number of other animals and invertebrates. Photo courtesy Sandi Culliker/www.shutterstock.com

⮝ The perentie is now going to be studied as part of this research project. Photo courtesy Chris Watson/www.shutterstock.com

⮝ Gould's monitor also buries its eggs to a great depth underground. Photo courtesy Ken Griffiths/www.shutterstock.com

⮝ Cane toads have adversely affected monitor numbers, and thereby affected the wider ecosystem. Photo courtesy Peter Yeeles/www.shutterstock.com

The arrival of the toxic cane toad (*Rhinella marina*) emphasised the extent of the monitor lizard's impact on the food web. In studies conducted between 2009 and 2017, Doody's research team uncovered abandoned burrows and an increase in the lizard's prey, including smaller lizards, snakes, turtles and birds. Australian researchers and natural resource managers have been unable to control cane toad numbers successfully.

Doody is planning to expand his research to include the perentie (*Varanus giganteus*), the largest species of monitor lizard or goanna in Australia. Believed to nest at great depths in the Australian desert as well, he is keen to discover whether it too should be deemed an ecological engineer. His team is also looking at how climate warming will impact on these animal communities.

Further information

J. Sean Doody, Kari F. Soennichsen, Hugh James, Colin McHenry, Simon Clulow. **Ecosystem engineering by deep nesting monitor lizards.** *Ecology*, 2020; DOI: 10.1002/ecy.3271

Secrets of the most deadly rattlesnake revealed

The tiger rattlesnake (*Crotalus tigris*) possesses the simplest yet most toxic venom of any rattlesnake species, and now new research from a team led by a University of South Florida (USF) biologist can explain the genetics behind the predator's fearsome bite.

USF Department of Integrative Biology Assistant Professor Mark Margres and colleagues across the southeastern USA have sequenced the genome (or genetic make-up) of the tiger rattlesnake to understand the genotype of the venom trait. Despite the simplicity of the tiger rattlesnake's venom, Margres says it is roughly 40 times more toxic than the venom of the eastern diamondback rattlesnakes (*Crotalus adamanteus*) found in Florida.

The importance of genetical research

This new study provides the most complete characterisation of the venom gene-regulatory network to date and its identification of key mechanisms in producing the particularly toxic venom will help scientists explain a wide array of genetic questions. "Simple genotypes can produce complex traits," Margres said. "Here, we have shown the opposite is also true - a complex genotype can produce simple traits."

Margres collaborated with colleagues at Clemson University, Florida State University and the University of South Alabama, in the

The tiger rattlesnake is the most deadly of all rattlesnakes. This new study reveals why this is the case. Photo courtesy Ali Iyon Photography/www.shutterstock.com

⮝ The eastern diamondback rattlesnake (*Crotalus adamanteus*) coiled here in strike pose, tongue out and raised, with its rattle held next to its head. In comparison, the degree of toxicity from a bite of the tiger rattlesnake is far greater. Photo courtesy Dan Reicjk/www.shutterstock.com project, which sought to explain whether trait differences are derived from differences in the number of genes, their sequence or how they are regulated. Their work is only the second time a rattlesnake genome has been decoded.

An organism's genotype is the set of genes it carries, and its phenotype is all of its observable characteristics, as shown by its appearance, which can be influenced by its genes, the environment in which it lives, and other factors. Evolutionary biologists work to understand how genes influence the variation in phenotype among otherwise similar organisms. In this case, they looked at why different species of rattlesnakes produce venom which vary in composition and toxicity.

A surprisingly simple system

Tiger rattlesnakes are native to the Sonoran Desert of southern Arizona and northern Mexico where this relatively small pit viper preys on lizards and rodents. While some species of rattlesnakes have complex venoms that are the result of scores of genes, Margres said the tiger rattlesnake's venom is quite simple – as few as 15 of its 51 toxic-producing genes actively drive the production of the proteins and peptides (amino acid chains) that attacks its prey's nervous system, forces blood pressure to drop and causes blood clotting to cease.

The team found that the number of venom genes greatly exceeds the number of proteins produced in the simple phenotype, indicating a complex process was at the heart of the toxic venom and the tiger rattlesnake even has toxic genes to spare.

"Only about half of the venom genes in the genotype were expressed," Margres said. "To me, the interesting part is why are the non-expressed genes still present? These genes can make functional toxins, they just don't. That needs to be explored further."

⮝ The habitat of the tiger rattlesnakes lies in the Sonoran desert, in the US state of Arizona. Photo courtesy Anton Foltin/www.shutterstock.com

Further opportunities

Beyond understanding this one species of venomous snake, Margres says the research will help to advance genetic science by showing the techniques more commonly used on genetic research with mice and fruit flies, (which are organisms that are often used in such studies), can also work when applied to others that feature less often in this field of research, such as snakes.

The researchers used genetic sequencing techniques that are common in research into human genetics and, by doing so, opened the door for scientists to understand the genotype-phenotype relationship in many other organisms.

Another potential side benefit of the research, Margres said, is that snake venom is used in medicine for humans to combat stroke and high blood pressure. The more scientists understand about venom, the better medical engineering can apply that knowledge in drug discovery and development.

⮝ The tiger rattlesnake is so-called because of its striped patterning. Photo courtesy Rusty Dodson/www.shutterstock.com

⮝ The advent of gene sequencing has allowed new insights into the production of snake venom. Photo courtesy gopixa/www.shutterstock.com

Further information

Mark J. Margres, Rhett M. Rautsaw, Jason L. Strickland, Andrew J. Mason, Tristan D. Schramer, Erich P. Hofmann, Erin Stiers, Schyler A. Ellsworth, Gunnar S. Nystrom, Michael P. Hogan, Daniel A. Bartlett, Timothy J. Colston, David M. Gilbert, Darin R. Rokyta, Christopher L. Parkinson. **The Tiger Rattlesnake genome reveals a complex genotype underlying a simple venom phenotype.** *Proceedings of the National Academy of Sciences*, 2021; 118 (4): e2014634118 DOI: 10.1073/pnas.2014634118

Snakes versus lizards

A view of some of the islands forming the Izu peninsula, where this study was carried out. Photo courtesy torero reaction/www.shutterstock.com

In a study spanning four decades, researchers from the University of Hong Kong's Research Division for Ecology & Biodiversity (HKU) in the Faculty of Science, and Toho University's Department of Biology (Toho), Japan, have discovered that predation by snakes is pushing lizards to be active at warmer body temperatures on islands where snakes are present, in comparison to islands free from snakes.

Their work also detected significant climatic warming throughout the years and found lizard body temperatures have also increased accordingly. The findings show that lizard thermal biology can be highly dependent on predation pressures and that body temperatures are rising, which suggests that such ectothermic (cold-blooded) predator-prey relationships may be changing as the result of climatic warming.

The Japanese four-lined rat snake (*Elaphe quadrivirgata*) occurs on some islands where the skink is also to be found. Photo courtesy optimarc/www.shutterstock.com

The battle for survival on the Izu Islands

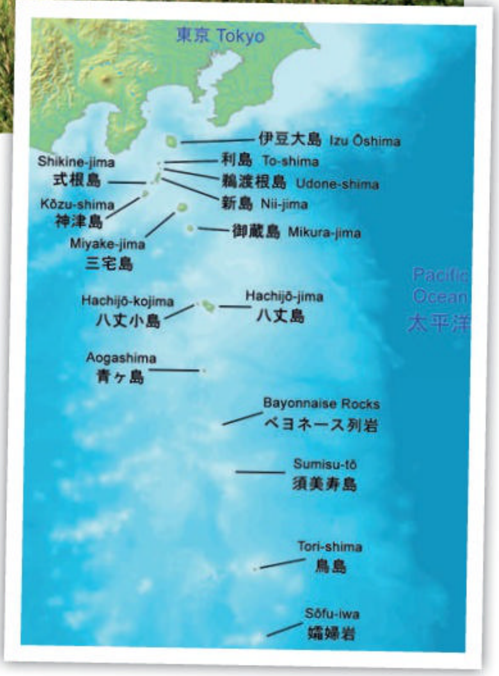
This research is the first to present long-term observations on the thermal biology behind the prey-predator relationship of snakes and lizards on the Izu Islands. Less than a million years old, these islands are located near the southeastern coast of the Japanese mainland and represent a valuable natural laboratory for studying ecological and evolutionary processes.

Similar to the reasons initially drawing evolutionary biologists to the Galápagos, this simplified island environment with low numbers of species overall provides a rare direct opportunity to study selective pressures on species.

In this case, one dominant lizard species is found on all these islands; Okada's five-lined skink (*Plestiodon latiscutatus*). Its mainland predator, the Japanese four-lined rat snake (*Elaphe quadrivirgata*), is found on most but not all of them. This has resulted in skink populations that have experienced different evolutionary pressures: either free from or subject to predation by these particular rat snakes.

A long-term project

The research was conducted by Félix Landry Yuan (HKU) and Shun Ito (Tohoku University's Graduate School of Life Science) and led by Dr Timothy Bonebrake (HKU) and Professor Masami Hasegawa (Toho). Initial observations and data collection were first started by Prof Hasegawa during the early 1980s, when he first noticed lizard behaviour differed on islands with and without populations of snakes.



A map showing the Izu islands which lie to the south of the main Japanese island of Honshu. Courtesy www.demis.nl/PD.

Prof Hasegawa has subsequently continued to visit the islands each year to catch lizards and snakes for body temperature and morphological (body) measurements. Thanks to his efforts, this research has revealed that annual temperatures across the Izu Islands have increased by just over 1°C (1.8°F) since he first started his observations, and that the body temperature of the lizards has also increased by the same magnitude.

Tohoku University's Professor Masami Hasegawa on Oshima. Photo courtesy Félix Landry Yuan.

Picturesque Kozu Island. With an approximate 3-10 hour boat ride from Tokyo, depending on the island, the Izu Islands are directly accessible from the Japanese capital, although inter-island travel is not as easy. For their field work, the researchers stayed at local family-run guest houses, and travelled to their study sites in the early morning where they searched for lizards until the late afternoon. Photo courtesy Félix Landry Yuan.

Higher body temperature helps the lizards

In addition to body temperature measurements, Félix Landry Yuan took a portable racetrack, tripod and camera to the islands on this occasion to measure the speed at which lizards ran at different temperatures. By analysing the thermally dependent running speeds of over 150 lizards across the islands, the researchers were able to establish how predation by snakes affected lizard thermal biology and the probable consequences for their fitness.

Dr Bonebrake notes that: "By racing lizards which had different body temperatures down a track, Félix was able to show that optimal temperatures were higher for lizards on the island with snakes, being consistent with the high body temperatures observed on the island.

"Shun Ito was also able to identify differences in lizard hind leg length that had consequences for their survival. Thus, the combination of higher body temperatures and morphological differences help the lizards run faster and they are better placed to escape the snakes. The exciting and unique aspect of this work is how the experimental work matches and supports the extensive natural history data and observations."

A Japanese four-lined rat snake on Kozu Island. Photo courtesy Félix Landry Yuan.

The impact of climate change

With climate change ongoing, the dynamics of this prey-predator relationship could be affected on islands with snakes, as lizard body temperatures are likely to continue to rise. This will probably make it harder for the snakes to catch their prey, and so could ultimately lead to a fall in their numbers.

In addition, as predation has considerable consequences for the thermal biology of their prey, the presence or absence of snakes could differentially influence the general vulnerability of lizards to climatic warming across the islands.

The Izu Islands demonstrate the value of island systems, in teasing apart mechanisms through which predation directly influences behaviour, morphology and physiology of prey species. On the other hand, understanding the ways in which predation can affect prey responses to climate change requires long-term study.

This international collaboration between HKU and Toho used these unique properties of this system (and Professor Hasegawa's forethought and intensive data collections since the 1980s) to show how predator-prey relationships may be vulnerable in a warming climate.

Okada's five-lined skink, which was the subject of this study. Photo courtesy Kwb/Wikipedia/CC BY-SA 3.0.

The body temperature of the lizards has risen on the islands over time. This individual was photographed on the island of Hachijo-Kojima. Photo courtesy Masami Hasegawa.

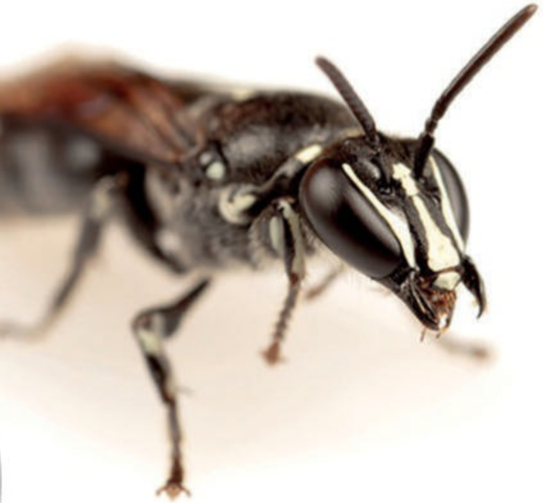
"It is a great pleasure to reveal ecological and evolutionary responses among prey and predator interactions by this international research team. I'm very hopeful that the Izu islands can become a key model island system to study ongoing evolution under global environmental change, by attracting ambitious young Asian biologists to research this subject further," adds Professor Hasegawa.

Further information

Landry Yuan F, Ito S, Tsang Tpn, Kuriyama T, Yamakazi T, Bonebrake Tc, Hasegawa M. **Predator presence and recent climatic warming raise body temperatures of island lizards.** *Ecology Letters*, 2021 DOI: 10.1111/ele.13671

Bee bounces back!

A widespread field search for a rare Australian native masked bee (*Pharohylaeus lactiferus*) that had not been recorded for almost a century found the species does in fact still exist – but is probably under increasing pressure to survive. Prior to this study, only six individuals had been found, with the last published record of this Australian endemic bee species being made during 1923 in Queensland.



A male example of the newly rediscovered masked bee. Photo courtesy James Dorey.

Flowers of the fire wheel tree are favoured by these bees. Photo courtesy Rose Makin/www.shutterstock.com

A widespread search

"This is concerning because it is the only Australian species in the *Pharohylaeus* genus and nothing was known about its biology," explains Flinders University researcher James Dorey. The search for the species began after bee experts Olivia Davies and Dr Tobias Smith raised the possibility of its extinction, based on the lack of any recent sightings. It was found again following an extensive sampling of 225 general and 20 targeted sampling sites across New South Wales and Queensland.

Along with extra bee and vegetation recordings from the *Atlas of Living Australia*, which lists 500 bee species in New South Wales and 657 in Queensland, the Flinders researchers sought to assess the latest levels of true diversity, warning that habitat loss and fragmentation of Australia's rainforests, along with wildfires and climate change, are likely to put extinction pressure on this and other invertebrate species.

Impact of forest clearances

"Three populations of this missing species were found by sampling bees visiting their favoured plant species along much of the Australian east coast, suggesting populations are isolated," explains James Dorey. Clearance of the bees' habitat and their potentially specialised feeding habits might explain the rarity of this species. Australia has already cut down more than 40% of its forests and woodlands since European colonisation, leaving much of the remainder fragmented and degraded.

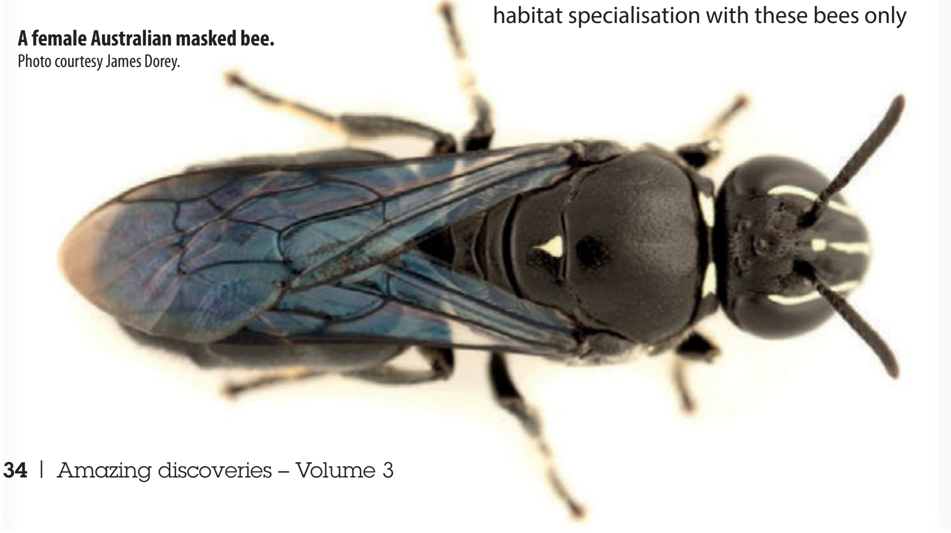
"My geographical analyses used to explore habitat destruction in the Wet Tropics and Central Mackay Coast bioregions indicate the susceptibility of Queensland rainforests and the bee populations to bushfires, particularly in the context of a fragmented landscape," he adds.

Specialised feeding habits?

The study also warns the species is even more vulnerable as these bees appear to favour specific types of flower and were only found near tropical or sub-tropical rainforest – a single vegetation type.

"Collections indicate possible floral and habitat specialisation with these bees only visiting firewheel trees (*Stenocarpus sinuatus*), and Illawarra flame trees (*Brachychiton acerifolius*), to the exclusion of other available floral resources," says James Dorey.

The known populations of this masked bee are restricted and susceptible to habitat destruction, arising from changed land use or events such as fires. "Future research should aim to increase our understanding of the biology, ecology and population genetics of the species. If we are to understand and protect these wonderful Australian bees, we really need to increase biomonitoring and conservation efforts, along with funding for museum curation and digitisation of their collections and other initiatives," advises James Dorey.



A female Australian masked bee. Photo courtesy James Dorey.

Widespread forest clearance has taken place in the Mackay region of Queensland for agriculture and other reasons. Photo courtesy Kealie Frerichs/www.shutterstock.com

Further information

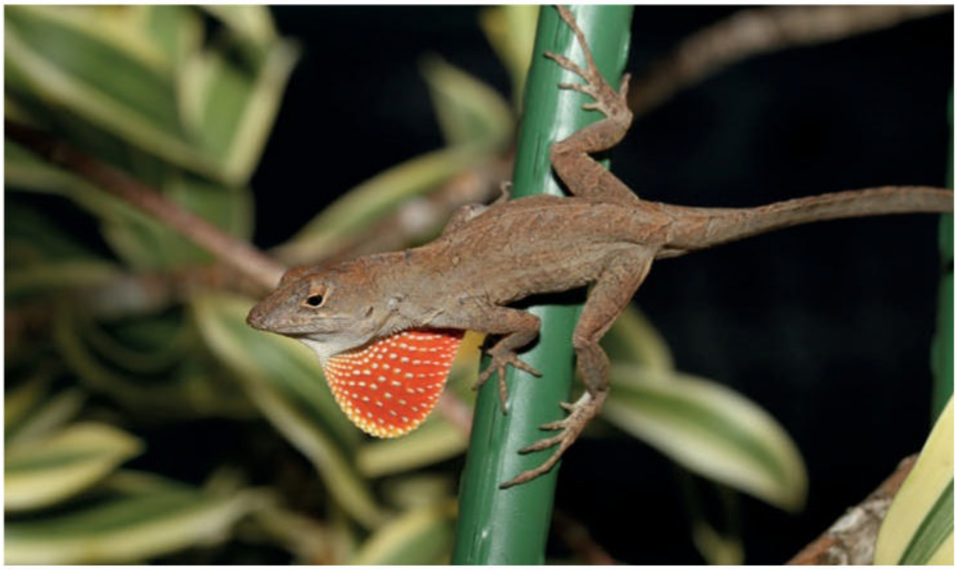
Dorey JB (2021) **Missing for almost 100 years: the rare and potentially threatened bee, *Pharohylaeus lactiferus* (Hymenoptera, Colletidae).** *Journal of Hymenoptera Research 81:* 165-180. https://doi.org/10.3897/jhr.81.59365

A colourful battle for survival

In the lizard world, flashy colours attract the interest of females looking for mates. But they can make a colourful male desirable to other eyes, too — as a meal!

Assistant Research Professor of Biological Sciences Lindsey Swierk, based at Binghamton University in New York, has been involved in an experiment involving clay models of water anoles (*Anolis aquaticus*), a species of lizard only found in Costa Rica and a small slice of Panama. The researchers conducted the experiment at the Las Cruces Biological Station in Costa Rica, which is one of the Organization for Tropical Studies' field stations.

In order to be noticed by would-be mates, male anoles have dewlaps, which are the colourful extendable flaps of skin under their chins. In most species of anole, dewlaps evolved to be as noticeable as possible within the environment, given the predominant colours and lighting conditions in that setting.



⮝ Otherwise dull-coloured anoles frequently display brightly-coloured dewlaps, as here in the case of this brown anole (*Anolis sagrei*). Photo by Michael Benard/www.shutterstock.com

Surprising variations in colouration

"Even so, we see a lot of variation within a species in just how bright dewlaps are," Swierk admits. While some water anoles have dramatic red-orange flaps, others have more muted colours, tending towards a dull brownish-red shade. Researchers wanted to determine the effect that these colour variations had on their risk of falling victim to predators.

While it's widely assumed that flashier males will attract more attention from predators, few studies actually test this assumption. Logistics may be a factor: researchers need to separate the effects of sexual colours from other aspects of a creature's body and behaviour, which is a difficult task when using real animals. As a result, many studies show correlation rather than causation.

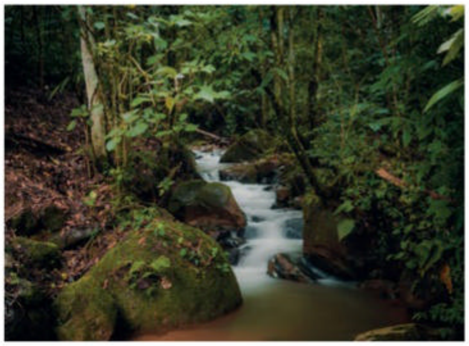
Making the models correctly

In order to examine whether more colourful males face greater risks of being attacked, the researchers created clay models with coloured dewlaps — some of which were brightly coloured, and others more muted. Luckily, many visual predators use a stereotyped "search image" to identify prey, so the models only had to approximate anoles' general size, colour and shape. The actual colour of the dewlap, however, required special attention.

"Since different animals have varying visual sensitivities compared with ours as humans, getting the colours right was an important consideration in our model design," Swierk explains. "We ran some pilot trials before this experiment, so as to make sure our models were convincing as 'lizards' — and they certainly seemed to be, as many birds and other lizards took bites out of them!"

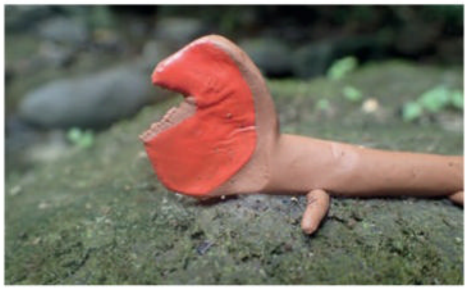
Live fast, die young?

Researchers were able to identify predators from bite marks in the clay models. They included many species of bird, including the strikingly beautiful motmot with its serrated beak. Basilisks and whiptail lizards were also among the likely attackers. The results proved that flashier lizards really do end up being eaten more often.



⮝ Typical habitat for this species in the Central American country of Costa Rica.
Photo courtesy Stiven Beitia R/www.shutterstock.com

⮝ Aside from their dewlap, water anoles are not brightly coloured, and blend into their background, as here in a stream. Photo courtesy Lindsey Swierk.



⮝ A clay model of a water anole with the serrated beak-mark from a type of predatory bird known as a motmot. Photo courtesy Lindsey Swierk.

If bright colours have deadly consequences however, why do female anoles prefer them? One answer is that brighter males have either high-quality genetic material or resources that allow them to handle the risk of getting eaten, according to Swierk.

"Because every individual's evolutionary 'mission' in life is to pass on as many copies of its genes as it can, conspicuous traits like these can evolve if they give an individual a high level of reproductive success — even if the flashy trait ends up killing them in the end," Swierk explains.

Further information

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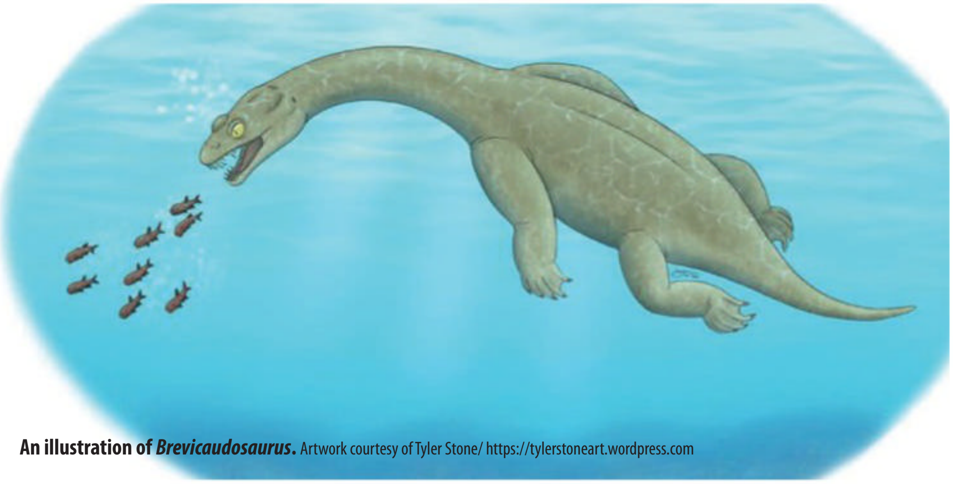
A new type of reptile discovered

About 240 million years ago, when reptiles ruled the ocean, a small lizard-like predator floated near the bottom in shallow water, picking off prey with its fang-like teeth. A key feature, in the form of its short and flat tail, used for balance, helped to reveal this was a previously unknown species.

Palaeontologists at the Chinese Academy of Scientists and Canadian Museum of Nature have analysed two skeletons from a thin layer of limestone unearthed in two quarries in southwest China. They identified the skeletons as nothosaurs. These are marine reptiles which lived during the Triassic period, with a small head, fangs, flipper-like limbs, a long neck, and normally an even longer tail, probably used for propulsion. However, in the new species, the tail is short and flat.

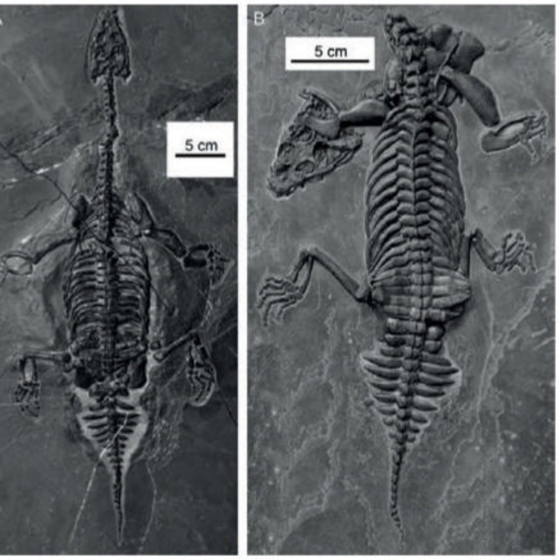


An illustration of *Brevicaudosaurus*. Artwork courtesy of Tyler Stone/ https://tylerstoneart.wordpress.com

A distinctive appearance

"Our analysis of two well-preserved skeletons reveals a reptile with a broad, pachyostotic (meaning 'denser boned') body and a very short, flattened tail. A long tail can be used to flick through the water, generating thrust, but the new species we've identified was probably better suited to hanging out near the bottom in shallow sea, using its short, flattened tail for balance, like an underwater float, allowing it to preserve energy while searching for prey," says Dr Qing-Hua Shang from the Chinese Academy of Sciences, in Beijing.

The scientists have named the new species as *Brevicaudosaurus jiyangshanensis*, from the Latin 'brevi' for 'short,' 'caudo' for 'tail,' and the Greek 'sauros' for 'lizard.' The most complete skeleton of the two was found in Jiyangshan quarry, which was used for the naming the actual species. These prehistoric reptiles measured just under 60cm (24in) long.



⮝ The fossilised remains of the specimens unearthed in southwest China. Note the broad flattened tail. Images courtesy Qing-Hua Shang, Xiao-Chun Wu and Chun, Journal of Vertebrate Paleontology.

Their likely lifestyle

Study of the skeletons gives further clues regarding their lifestyle. The forelimbs are more strongly developed than the hind limbs, suggesting they played a role in helping the reptile to swim. However, the bones in the front feet are short compared with those of other species, limiting the power with which brevicaudosaurus could pull through the water. Most of its bones, including the vertebrae and ribs, are thick and dense, further contributing to the stocky, stout appearance of the reptile. This design of the skeleton would have limited its ability to swim quickly.

However, thick, high-mass bones act as ballast. What the reptile lost in speed, it would have gained in stability. The development of dense bones, known as pachyostosis, may have made it neutrally buoyant in shallow water. Together with the flat tail, this would have helped brevicaudosaurus to float motionless underwater, requiring little energy to stay horizontal. Neutral buoyancy should also have enabled it to walk on the seabed searching for slow-moving prey as well.

Highly dense ribs may also indicate the reptile had large lungs. As suggested by the lack of firm support of their body weight, nothosaurs were oceanic but they needed to come up to the water surface in order to breathe. They have nostrils on the snout for this purpose, while large lungs would have increased the time the species could spend under water.

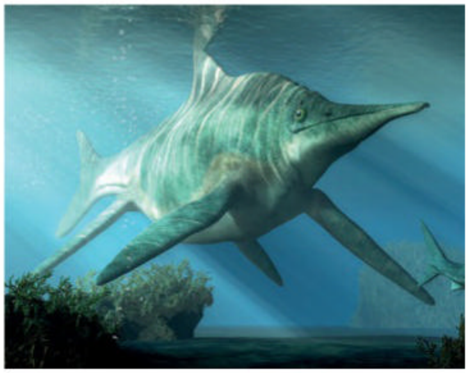
An unexpected finding

The new species features a bar-shaped bone in the middle ear called the stapes, used for sound transmission. The stapes is generally lost in nothosaurs and marine reptiles generally during fossilisation. Scientists had predicted that if a stapes was found in a nothosaur, it would be thin and slender, as in other species of this branch of the reptilian family tree.

However, in *B. jiyangshanensis*, it is thick and elongate, suggesting it had good hearing underwater. "Perhaps this small, slow-swimming marine reptile had to be vigilant for large predators as it floated in the shallows, as well as being a predator itself," suggests Dr. Xiao-Chun Wu from the Canadian Museum of Nature.

Further information

Qing-Hua Shang, Xiao-Chun Wu, Chun Li. **A New Ladinian Nothosauroid (Sauropterygia) from Fuyuan, Yunnan Province, China.** *Journal of Vertebrate Paleontology,* 2020; e1789651 DOI: 10.1080/02724634.2020.1789651



⮝ There were large predators in the seas of the Triassic Period, including shastasaurus, an ichthyosaur which is the largest known marine reptile ever discovered, growing to nearly 18.5m (60ft) long, seen here in the company of early sharks. Its remains have been unearthed in China. Staying in the shallows may therefore have given brevicaudosaurus some protection from these fearsome giants. Artwork courtesy Daniel Eskridge/www.shutterstock.com

How papillomas spread in turtles

University of Central Florida researchers are homing in on the cause of a major disease of sea turtles, with some of their latest findings implicating saltwater leeches as a possible factor. The disease, known as fibropapillomatosis (FP) causes sea turtles to develop tumours on their bodies, which can limit their mobility and also adversely affect their health by interfering with their ability to catch and eat prey.

Groups of turtles congregating in an area, like these green turtles (*Chelonia mydas*), and coming into contact increases the likelihood of this infection spreading. Photo courtesy blue-sea-cz

The likely suspect

While the cause of FP isn't known, saltwater leeches have been suspected in playing a role because of their frequent presence on areas of sea turtles where FP tumours often develop, such as on their eyes, mouths and flippers.

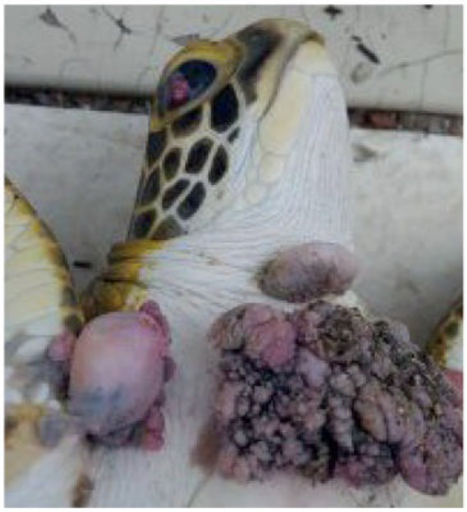
Leah Rittenburg who spearheaded the research and was responsible for the genetic analyses. Photo courtesy MTRG. Permits MTP-231 and NMFS #19508.

The results are the first evidence of a significant association between leeches and the disease in sea turtles, according to the researchers.

"Florida is one of the areas most heavily impacted by FP," says Anna Savage, an associate professor in UCF's Department of Biology and study co-author. "Over the past three decades, approximately half of the green turtle juveniles encountered in the Indian River Lagoon have FP tumours, which is one of the highest rates documented," she says.

Sea turtle health is important because the ancient marine reptiles contribute to healthy oceans and coastlines by grazing and maintaining sea grass beds.

All sea turtles are already categorised as threatened or endangered because of threats from pollution, coastal development and fishing, in addition to infectious diseases.

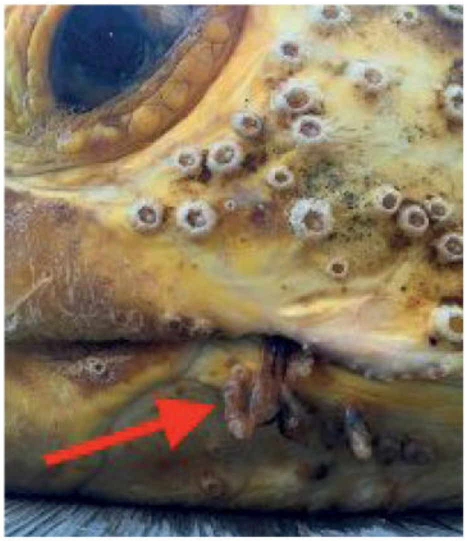

FP causes sea turtles to develop tumours on their bodies, which can limit their health and mobility. Photo courtesy Jake Kelley. Permits MTP-231 and NMFS #19508.

The investigation

Knowing if leeches play a role in the disease transmission can help researchers better understand and predict its spread, as well as inform conservation actions, such as leech removal in sea turtle rehabilitation centers.

To find out a possible connection between leeches and FP, the researchers documented the presence of leeches on green and loggerhead turtles (*Caretta caretta*) captured from the Indian River Lagoon and also used genetic analyses to determine if leeches collected from the turtles contained chelonid alphaherpesvirus 5 (ChHV5), the virus most likely to be responsible for the development of the disease in an individual turtle.

Turtle Nesting
Beach
Street Lights
Turned Off
Mar Thru Oct
NEXT 1 1/2 MILE
Central Florida's Atlantic coastline hosts about one-third of all green turtle nests in the state and is one of the most important nesting areas in the world for loggerheads. Photo courtesy Serenrthos/www.shutterstock.com


Saltwater leeches have been suspected to play a role in FP due to their frequent presence on areas of sea turtles where FP tumours often develop. An arrow points to a leech. Photo courtesy Chris Long. Permits MTP-231 and NMFS #19508.

"Our historical data, collected by the UCF Marine Turtle Research Group between 2006 and 2018, revealed that leech parasitism was significantly associated with FP in green turtles but not in loggerhead turtles," Rittenburg says. "For the genetic analysis, about one-fifth of the leeches we collected were positive for ChHV5, and one leech species trended towards coming from FP-positive turtles, further supporting the hypothesis that leeches may act as ChHV5 transmitters."

Now that the researchers have demonstrated a relationship between FP and leeches, they want to evaluate more specifically if leeches transmit the turtle herpesvirus, which would provide stronger evidence that the virus is an underlying cause of FP.

Further information

LT Rittenburg, JR Kelley, KL Mansfield, AE Savage. **Marine leech parasitism of sea turtles varies across host species, seasons, and the tumor disease fibropapillomatosis.** *Diseases of Aquatic Organisms,* 2021; 143: 1 DOI: 10.3354/dao03549

Egg-laying behaviour in loggerhead sea turtles aids survival

Not all in one basket: loggerhead sea turtles lay their eggs in multiple locations to improve reproductive success. Photo courtesy Trevor Charles Graham/www.shutterstock.com

Although loggerhead sea turtles (*Caretta caretta*) return to the same beach where they hatched to lay their eggs, a new study by the University of South Florida (USF) finds individual females lay numerous clutches of eggs in locations miles from each other, so as to increase the chance that some of their offspring will survive. Some females lay as many as six clutches as far as 9.6km (6ml) apart during the same breeding season.

Increasing the options for success

"Nesting females don't lay all their eggs in one area. Their reproductive strategy is like investing in a mutual fund. Females divide their resources among many stocks rather than investing everything in a single stock," explains Deby Cassill, biology professor at USF's St. Petersburg campus.

During her 50 year lifetime, a single female loggerhead will produce around 4,200 eggs and scatter them at 40 different sites on the barrier island. This strategy helps reduce the risk of complete reproductive failure caused by hurricanes and thunderstorms that could wash out or flood all clutches.

"Because females diversify reproduction in unpredictable patterns over time and space, nearly two-thirds of loggerhead sea turtle hatchlings made it into the Gulf of Mexico," says Cassill.

⮝ Fresh nesting tracks on a beach in Florida. There is no guarantee this female will return here again in the breeding season. Photo courtesy Thomas Barrat/www.shutterstock.com

On-going monitoring

For the study, Cassill analysed 17 years of data provided by the Conservancy of Southwest Florida on loggerhead females nesting on Keewaydin Island off the southwestern Gulf coast of Florida. For years, conservancy staff and community volunteers tagged turtles and patrolled the island to monitor and record detailed information on the nesting population.

A young loggerhead turtle heads to the sea. The chances of successful hatchings are increased when females lay on different beaches, and because of this reproduction strategy, nearly two-thirds of loggerhead sea turtle hatchlings made it into the Gulf of Mexico.
Photo courtesy Tommy Daynjer/www.shutterstock.com

Though the study shows most sea turtle hatchlings reach the Gulf of Mexico, future impacts due to human encroachment and climate change could affect the population. Increased frequency of extreme storms due to warmer waters and sea-level rise may flood or wash away larger portions of clutches, leading to population declines of the threatened species.

The survival of the next generation

"It's important to follow individuals over time to really get a glimpse of how they mate, find food and ensure that some of their young survive to maturity. Without knowledge of the sea turtle's survival and reproductive biology, we cannot develop and implement effective conservation policies," says Cassill, who is studying the 'maternal risk management model', which looks at how natural selection pressures, such as predators, storms and resource scarcity, influence how mothers invest in offspring quantity and care.

She argues turtles and fish invest in large numbers of offspring when the likelihood their offspring will be killed by predators is high. Mammalian mothers like whales and elephants provide extensive care to one offspring at a time when the probability their young could starve is high. The model, based on the number and size of offspring produced by a mother, extends Darwin's theory of natural selection by explaining the fusion of parents and offspring into family units and societies.

Further information

Deby L. Cassill. **Multiple maternal risk-management adaptations in the loggerhead sea turtle (*Caretta caretta*) mitigate clutch failure caused by catastrophic storms and predators.** *Scientific Reports,* 2021; 11 (1) DOI: 10.1038/s41598-021-81968-0

An increasing frequency of storms and hurricanes represent a major hazard to the viability of turtle nests on Florida's coastline. Photo courtesy forestpath/www.shutterstock.com

New millipede discovered in a very unusual locality

Hearing the words "new species discovered" may conjure images of deep caves, uncharted rainforests, or hidden oases in the desert. But the reality is that thousands of new species are discovered each year by enterprising scientists all over the world. Many of these new species do come from exotic locations, but more surprisingly, many come from just down the road, including the newest member of the Hokie Nation - a millipede now known to science as *Nannaria hokie*.

Found on home turf

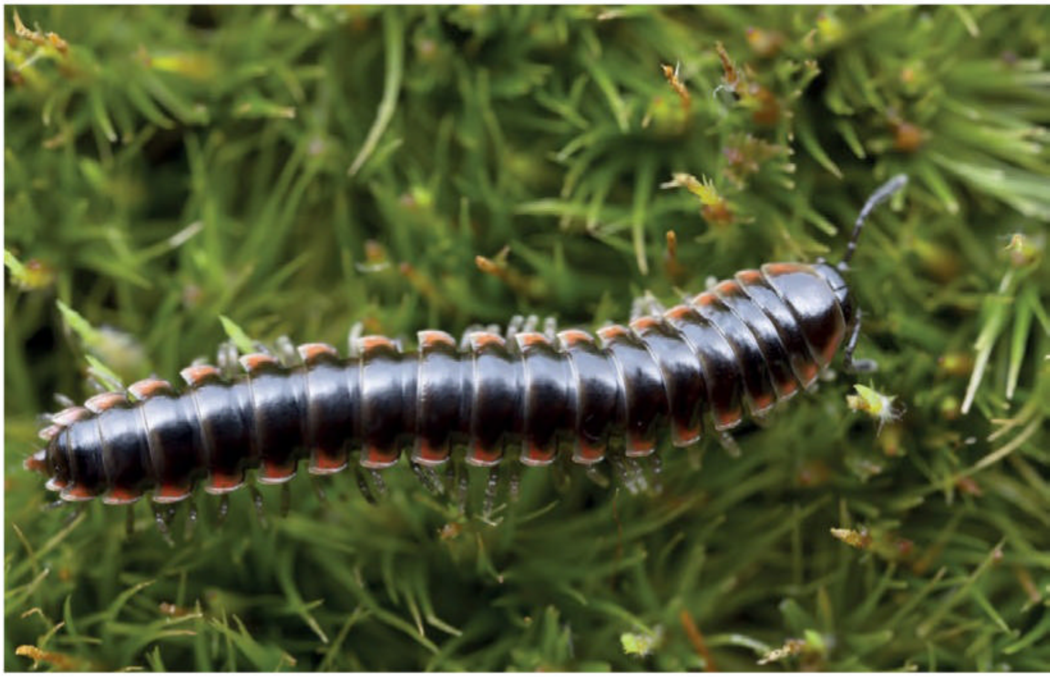
This newest Hokie — which has about 60 more legs than the HokieBird, the turkey mascot of Virginia Tech! — was discovered living under rocks by the Duck Pond behind the Grove on Virginia Tech's Blacksburg campus. Since then, this newly identified millipede has been found at the area commonly referred to as stadium woods and in the town of Blacksburg as well.

"It's not every day that we find new species, let alone on our campus, so we wanted to name the new species for the Virginia Tech community and to highlight the importance of conserving native habitat in the region," explains Paul Marek, a systematics and taxonomy associate professor in Virginia Tech's Department of Entomology in the College of Agriculture and Life Sciences.

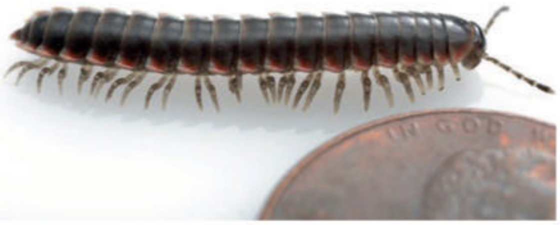
Nannaria hokie (pronounced "nan-aria ho-key") is about 2cm (0.78in) long, and a dark reddish millipede with yellow-white highlights (rather than maroon and orange!). These creatures usually find their home under rocks, leaves, and among other forest floor debris and so are not normally conspicuous.

A millipede study group

Millipede biodiversity is the primary focus of Paul Marek's lab, which investigates habitats all over the world, including Vietnam, Japan, and the United States. Marek and his colleagues recently published a paper that describes ten new species of millipedes, including the Hokie twisted-claw millipede, which was found only a stone's throw from Marek's lab window.



The Hokie twisted-claw millipede is one of scores of millipedes that entomologist Paul Marek has discovered and named over the years. Photo courtesy Paul Marek/Virginia Tech.



The common name of Hokie twisted-claw millipede comes from the presence of twisted claws on their feet before their reproductive organs.
Photo courtesy Paul Marek/Virginia Tech.

The announcement of these new species speaks to the biodiversity that has yet to be discovered, not just in far off exotic locations, but in your backyard.

"Millipedes are surprisingly abundant and diverse yet have thus far avoided major attention from both the scientific community and the public," says fellow researcher Jackson Means. "I guarantee that if you just go out into a forest near your home and start looking under leaves, you will almost certain find several species."

Millipede characteristics and naming

Millipedes are a unique group of arthropods that are characterised by having two pairs of jointed legs on most segments of their bodies. For anyone who may have turned over a rock in the dirt, the shiny exoskeleton of these particular arthropods should be familiar. Members of this group boast an incredible amount of biodiversity and have many fascinating and unique traits.

Some are brightly coloured, others glow in the dark, and a number can even exude cyanide in self-defence. Most millipedes are known as detritivores, or decomposers, and feed on decaying plant matter on forest floors.

Including the Hokie millipede, the new publication by Mark Marek and his team goes on to detail nine other millipedes, all native to Appalachian forests in the south-eastern USA.

As the scientists who discovered these arthropods, the Marek lab had the honour of naming these new species, for Virginia Tech alumnus and arachnologist Jason Bond (*Appalachioria bondi*), Ellen Brown (*Appalachioria brownae*), and even one for Mark Marek's wife, Charity (*Rudiloria charityae*). Marek found this particular millipede when taking a quick stroll with family before his wedding, along the Chagrin River in northeastern Ohio, where he grew up.

The millipede was first discovered on Virginia Tech's Blacksburg's campus, and subsequently in other areas around the town. Photo courtesy User:B/CC BY-SA 4.0.

Their environmental significance

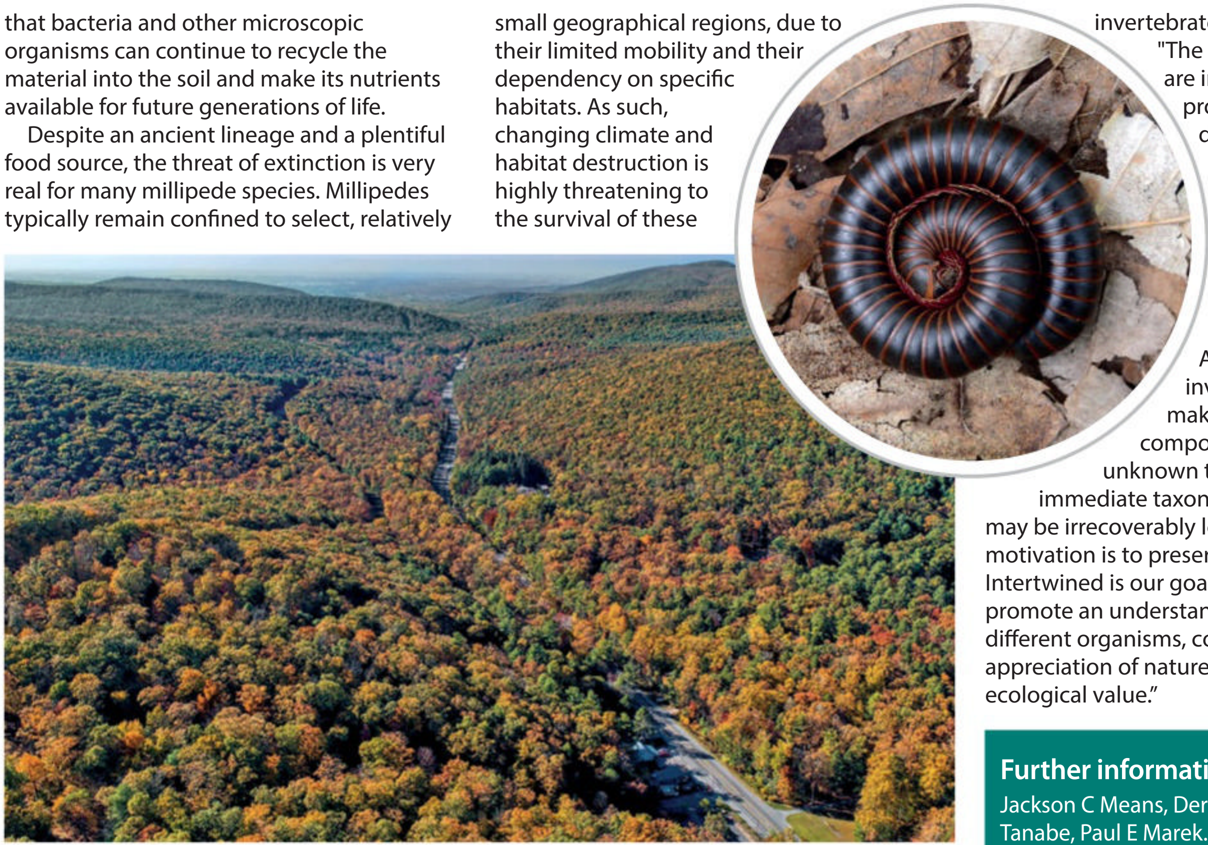
Millipedes have existed far longer than humans, and represent some of the first land animals discovered by scientists in fossil records. Their role as detritivores is crucial to forest ecosystems, and the primary role of millipedes in this environment is to break down plant matter into smaller material, so

⮝ **It was in an area in the woods near the Chagrin River in northeast Ohio where Mark discovered yet another new species of millipede - on his wedding day!** Photo courtesy Kenneth Sponster/www.shutterstock.com

that bacteria and other microscopic organisms can continue to recycle the material into the soil and make its nutrients available for future generations of life.

Despite an ancient lineage and a plentiful food source, the threat of extinction is very real for many millipede species. Millipedes typically remain confined to select, relatively small geographical regions, due to their limited mobility and their dependency on specific habitats. As such, changing climate and habitat destruction is highly threatening to the survival of these invertebrates.

"The forests of Appalachia are important carbon sinks, providing habitat for diverse species occupying many different parts of the food chain. Deforestation and habitat loss threaten this biodiversity," Marek explains. "Many Appalachian invertebrates, which make up the most varied component of this fauna, are unknown to science, and without immediate taxonomic attention, species may be irrecoverably lost. My lab's motivation is to preserve biodiversity. Intertwined is our goal to educate and promote an understanding of the biology of different organisms, combined with appreciation of nature and its immense ecological value."



⮝ **Paul Marek is certain there is much invertebrate life still to discover in the extensive and environmentally significant Appalachian forests.** Photo courtesy Open Tours LLC/www.shutterstock.com

Inset: An American millipede exposed on the forest floor, which results in it curling up into a defensive posture. Photo courtesy Kyle Selcher/www.shutterstock.com

Further information

Jackson C Means, Derek A Hennen, Tsutomu Tanabe, Paul E Marek. **Phylogenetic Systematics of the Millipede Family Xystodesmidae.** *Insect Systematics and Diversity*, 2021 DOI: 10.1093/isd/ixab003

THE OLDEST SKINK IN AUSTRALIA

Some of Australia's most famous animals – the wombat, platypus, kangaroos and the extinct marsupial thylacine – have been traced back to their fossil ancestors in remarkable finds made in central South Australia. Now a remote expedition to a large inland salt lake has sifted through remains unearthed in Namba Formation deposits to describe a tiny new skink, an ancestor of the well-known blue-tongue lizards.

The new species is Australia's oldest skink and lived 25 million years ago. It was found by Flinders University and South Australian Museum palaeontologists and volunteers at a rich fossil site on Lake Pinpa, which is located on the 602,000 square hectare (2325 sq miles) Frome Downs Station, seven hours drive north of state capital of Adelaide.

A rich location

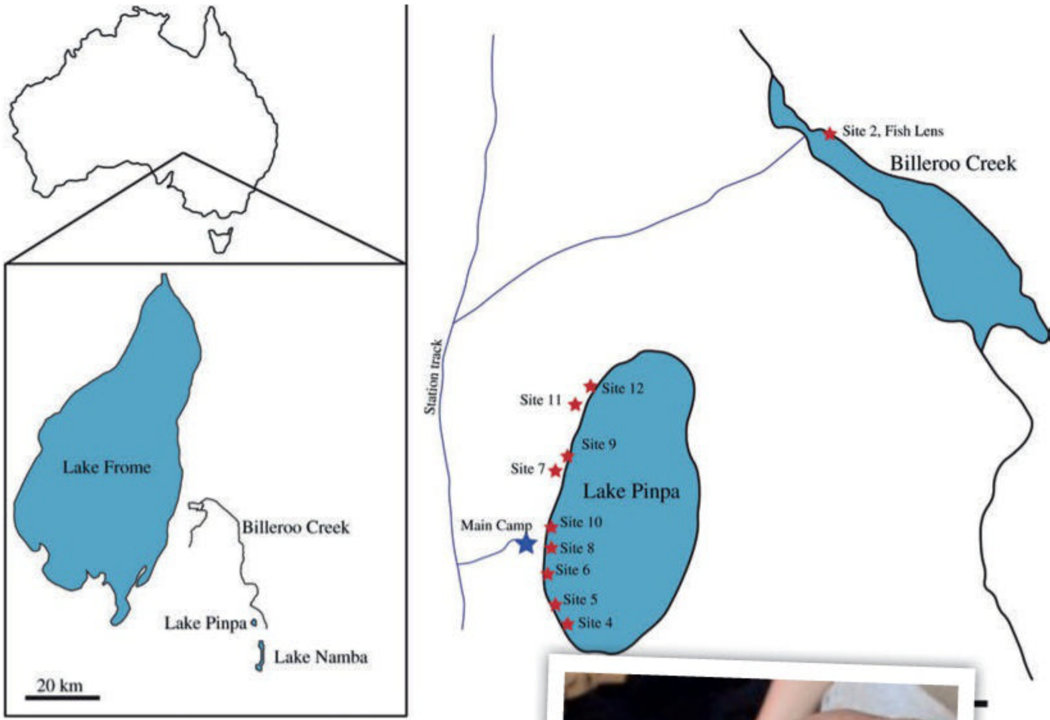
Following the crusted shoreline of a salt lake, the team homed in on a cross-section of sediments where fossil excavations of ancestors of the koala, a predatory bird, and fragments of a thylacine were previously unearthed. Remains of prehistoric fish, platypus, dolphins and crocodilians have also been found nearby.

"It was 45°C (equivalent to 113°F) in the shade that day, and it proved hard work digging through the clay, but it was definitely worth it once the tiniest of bone fragments turned out to be those of the oldest Australian skink," says palaeo-herpetologist Dr Kailah Thorn.

The once-verdant interior of Australia is considered the cradle of the continent's unique fauna and in particular its reptile diversity. "Fossil lizards are often too small to be identified when you're in the field. Lizard skulls are made of more than 20 individual bones that all fall apart, disarticulating when they fossilise," explains Dr Thorn, who now works as curator of the Edward de Courcy Clarke Earth Sciences Museum at the University of Western Australia.

⮝ **Professor Michael Bull studied sleepy lizard behaviours for more than three decades.** Photo courtesy Flinders University.

⮝ **The late Professor Mike Bull with Sir David Attenborough during filming of the BBC's *Life in Cold Blood*.** Photo courtesy Flinders University.



⮝ **The location of Lake Pinpa, set in context alongside the much larger Lake Frome, where these fossils were discovered.** Map courtesy K. M. Thorn, M. N. Hutchinson, M. S. Y. Lee, N. J. Brown, A. B. Camens and T. H. Worthy/https://doi.org/10.1098/rsos.201686. CC BY-SA 4.0.

➤ **Fossil remains found at the Lake Pinpa site.** Photo courtesy Flinders University.

The area is now a very inhospitable landscape today.
Photo courtesy Flinders University.

⮝ **Dr Kailah Thorn working in the field.** Photo courtesy Flinders University.

⮞ **Members of the Flinders University Palaeontology Laboratory in the field (left to right) Jacob Blokland, Associate Professor Trevor Worthy, Dr Kailah Thorn, Amy Tschirn, Nathan Brown and Dr Aaron Camens.** Photo courtesy Flinders University.

Luck and determination

The discovery of the tiny fossil lizards in an area which is the size of one million soccer fields was achieved by gaining an understanding of the geology of the region, and targeting fossil-containing bands of silt to sieve thoroughly and sort back at the lab. "These lizard fossils owe their discovery to the patient sorting of tiny bones," confirms vertebrate palaeontologist and Flinders University Associate Professor Trevor Worthy. "A teaspoon holds hundreds of tiny bones – all revealed in translucent splendour under a microscope."

"Once every 30 spoons something else is found among the fish – usually a tiny mammal tooth. But the discovery of the oldest skink was a golden moment for a palaeontologist," he explains.

Its position on the lizard tree of life

When researchers placed the fossil in the evolutionary tree of lizards, it was found to be an early member of the Australian skink subfamily Egerniinae – the group now encompasses blue-tongues, sleepy lizards (shinglebacks), land mullets and spiny-tailed skinks.

The name chosen for the newly described lizard – *Proegernia mikebulli* – commemorates the late Flinders University Professor Mike Bull, who passed away suddenly in late 2016. Inspiring generations of Australian herpetologists, Professor Bull's wide-ranging research career centred on social skinks from the Egerniinae subfamily: their behaviour, parasites, and conservation.

"Our colleague Professor Bull's long-term ecological studies of sleepy lizards were a massive contribution to biology," says co-author Matthew Flinders Professor Mike Lee. "The fossil record is essentially data from a long-term natural ecological study, so it is fitting that this fossil lizard is named in honour of Mike."

Further information

K. M. Thorn, M. N. Hutchinson, M. S. Y. Lee, N. J. Brown, A. B. Camens, T. H. Worthy. **A new species of *Proegernia* from the Namba Formation in South Australia and the early evolution and environment of Australian egerniine skinks.** *Royal Society Open Science*, 2021; 8 (2): 201686 DOI: 10.1098/rsos.201686

⮝ **The swamp skink (*Lissolepsis (=Egernia) coventryi*) is probably the closest member of the group alive today, in terms of its appearance to the fossil species. It also occurs in the south-eastern part of Australia.** Photo courtesy Sylvie Lebchek/www.shutterstock.com

A praying mantis from the age of the dinosaurs

A research team led by McGill University from Montreal in Canada has made a remarkable discovery. It has identified a new species of praying mantis thanks to imprints of its fossilised wings. This creature lived in Labrador, in what is now the Canadian subarctic region around 100 million years ago, during the time of the dinosaurs, in the Late Cretaceous period.

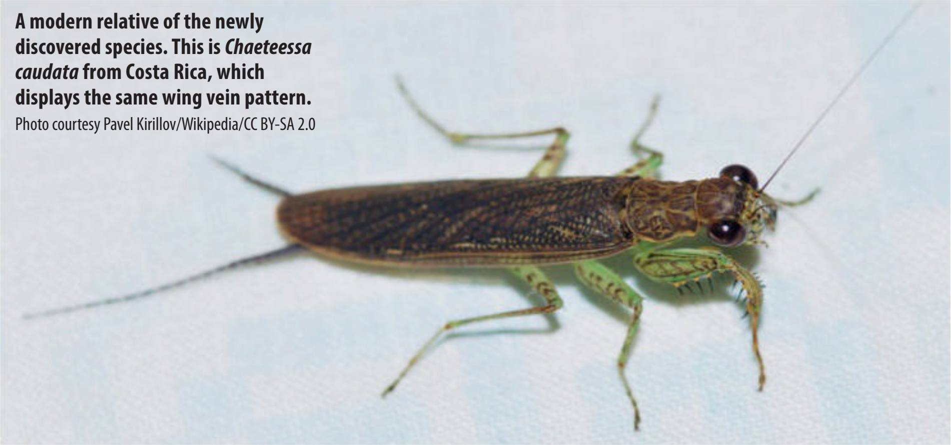
The researchers believe that the fossils of the new genus and species, christened *Labradormantis guilbaulti*, help to establish evolutionary relationships between previously known species and advances the scientific understanding about the evolution of the most 'primitive' modern praying mantises. The unusual find also sheds light on wing evolution among mantises and insects more generally.

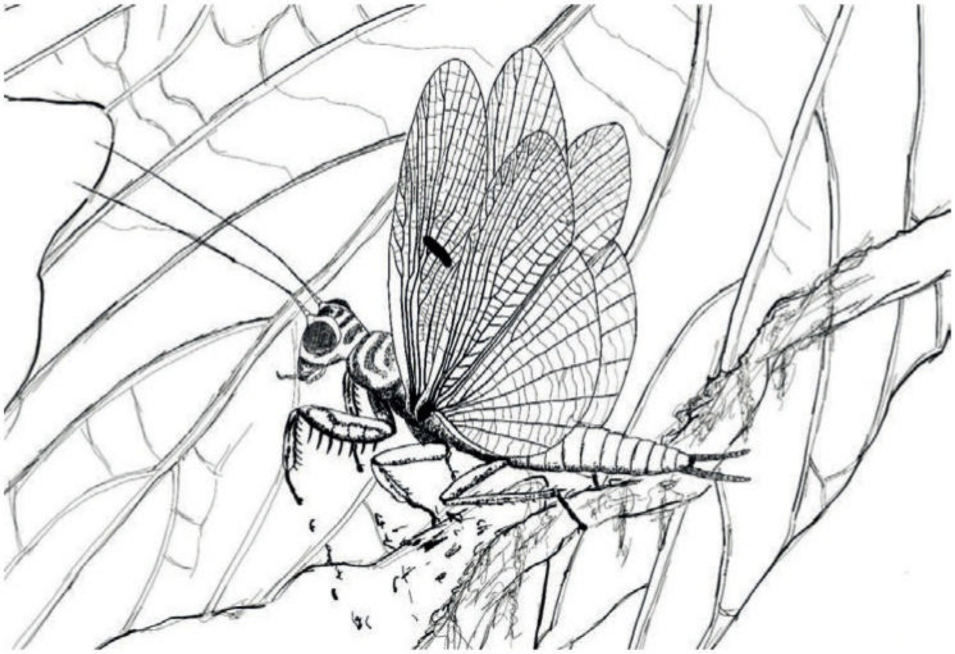
Digging through mountains

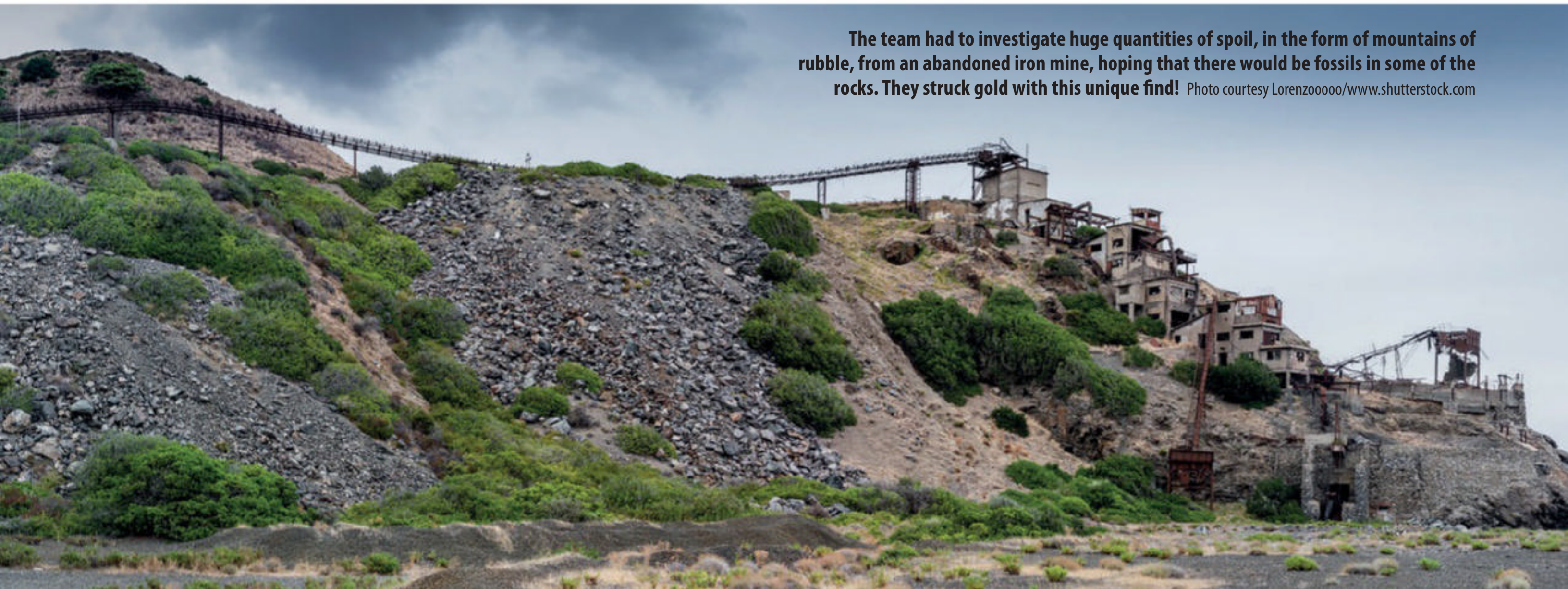
The research team, which included members from the Muséum national d'Histoire naturelle in Paris, and the Musée de paléontologie et de l'évolution in Montreal, found the specimens during fieldwork at an abandoned iron mine located in Labrador, near Schefferville in the state of Quebec.

"Our days were spent essentially scouring the surface of piles of rubble that had been excavated from the mine," says Alexandre Demers-Potvin. "Every now and then, one of the burgundy rocks on the ground would contain either a fossil leaf or a fossil insect, which we were able to collect. When the two fossils of *Labradormantis guilbaulti* were found in the field, none of us could identify them at first. It was only when I showed photos to palaeoentomologist Olivier Béthoux, that we started to think that we had the hind-wings of a previously unknown primitive mantis species."

The real surprise came when they were able to look more closely at a number of insect fossils in Dr. Béthoux's lab in Paris. Closer observations of certain specimens revealed


A modern relative of the newly discovered species. This is *Chaeteessa caudata* from Costa Rica, which displays the same wing vein pattern. Photo courtesy Pavel Kirillov/Wikipedia/CC BY-SA 2.0


⮝ A reconstruction of *Labradormantis guilbaulti* flying off from among the leaves of a sycamore tree, around 100 million years ago. The interpretation is based on fossils (for the wings) and living and extinct relatives (for the rest of the body). Fossilised sycamore leaves have been found in the same deposits as the mantis wings and show that this previously unknown insect species would have lived in a lush warm temperate forest during the Cretaceous. Artwork courtesy A. Demers-Potvin.

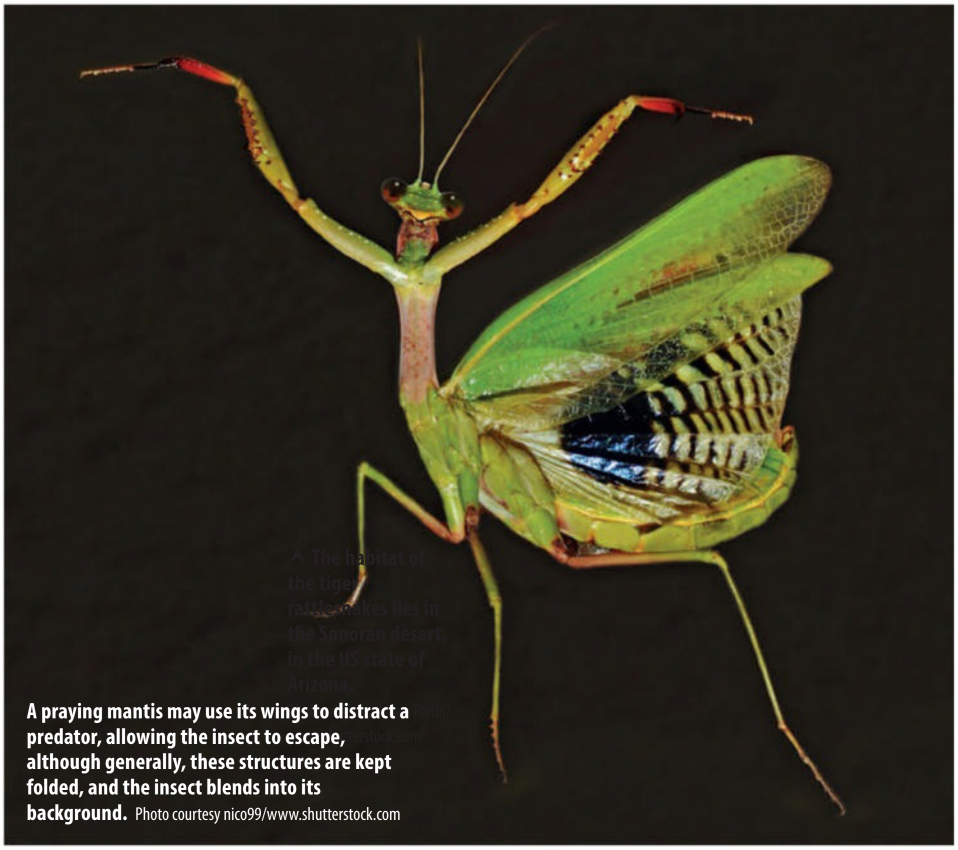

The team had to investigate huge quantities of spoil, in the form of mountains of rubble, from an abandoned iron mine, hoping that there would be fossils in some of the rocks. They struck gold with this unique find! Photo courtesy Lorenzooooo/www.shutterstock.com

they had not only the hind-wings but also the fore-wings of a hitherto unidentified species.

The significance of this find

A single vein has led to a revision of scientific understanding of mantis evolution. It was already known that most modern praying mantises, with their characteristic grasping forelegs, look very different from their oldest fossil ancestors. However, it has been difficult for palaeontologists to trace mantis evolution more precisely because of the multiple gaps in the fossil record of these insects, combined with the very different anatomies of the three most primitive modern mantis groups (Chaeteessidae, Mantoididae and Metallyticidae).

By using Reflectance Transformation Imaging (RTI), an emerging photographic method being used in palaeontology (fossil research), the researchers were able to get a better view of the intricate network of veins within the fossil wings. They noticed a vein lying along the hind-wing's folding line that is only found in one modern mantis lineage: the Chaeteessidae family. Following this key observation, they produced a revised evolutionary tree that included *Labradormantis* among some of its living and extinct relatives.


The habitat of the tiger rattlesnakes lies in the Sonoran desert, in the US state of Arizona.

A praying mantis may use its wings to distract a predator, allowing the insect to escape, although generally, these structures are kept folded, and the insect blends into its background. Photo courtesy nico99/www.shutterstock.com

Modern impacts

The identification of this single vein in this newly discovered species suggested that this structure had not evolved among Chaeteessidae in isolation, but that it was also present in extinct relatives of our modern mantises as well. The Chaeteessidae lineage is simply the only modern mantis group to retain it.

"It's very rare to advance our understanding of insect evolution without seeing a complete insect specimen trapped in amber," explains Hans Larsson, from McGill's Redpath Museum. "As a direct result of this find, however, we have a very rare case in which a less well-preserved fossil has a similarly high impact. We hope that this study inspires investigations of other wing impression fossils to address similar questions elsewhere in the insect evolutionary tree."

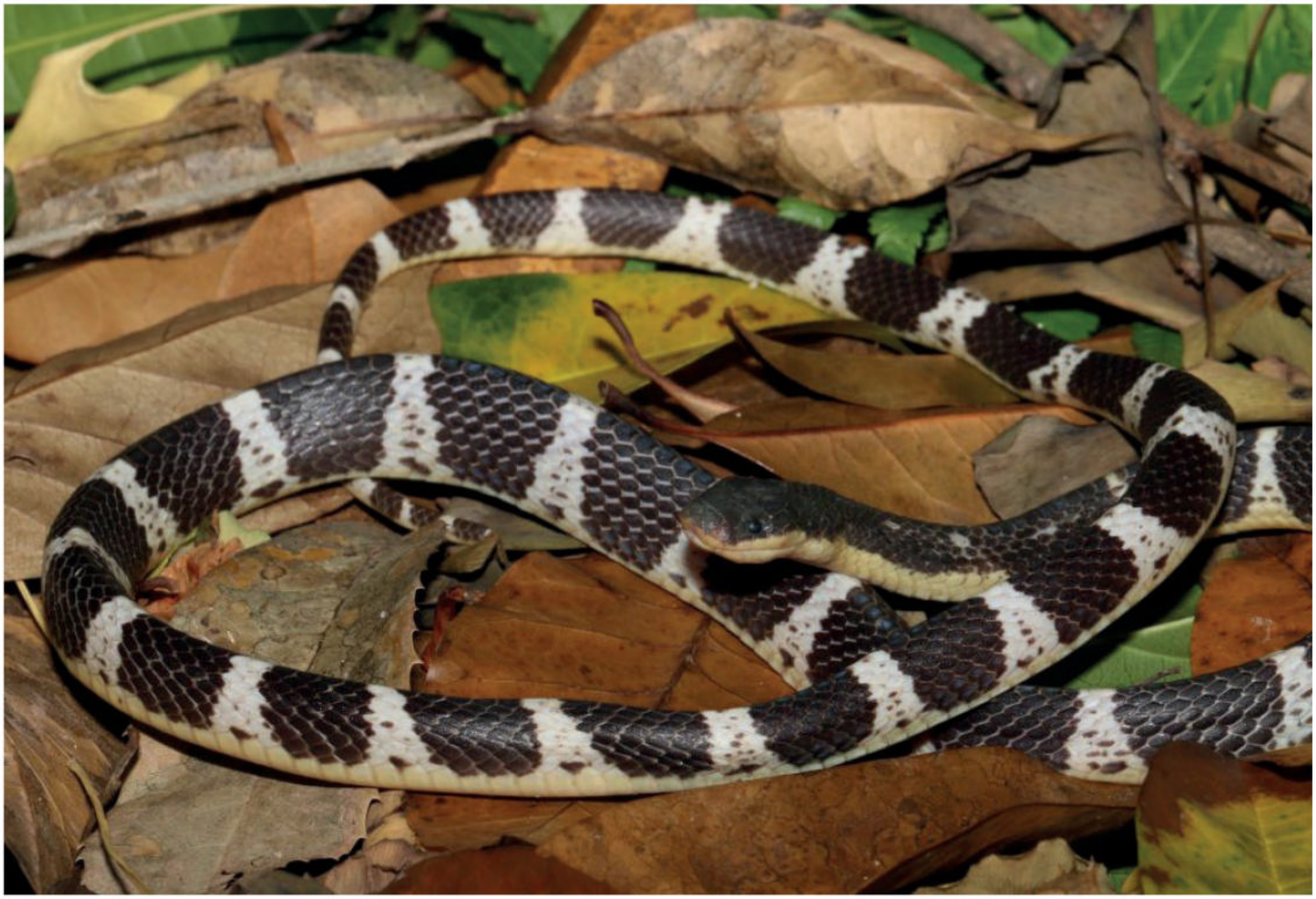
The two specimens described in this study are now part of the collections of the Musée de paléontologie et de l'évolution, Montréal, curated by M. Cournoyer.

Further information

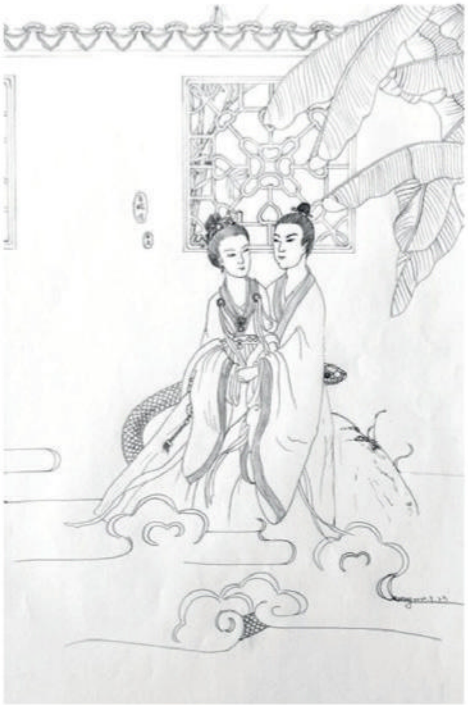
Alexandre V. Demers Potvin, Hans C.E. Larsson, Mario Cournoyer, Olivier Béthoux. **Wing morphology of a new Cretaceous praying mantis solves the phylogenetic jigsaw of early diverging extant lineages.** *Systematic Entomology*, 2021; 46 (1): 205 DOI: 10.1111/syen.12457

The area where the new praying mantis was discovered represents a harsh environment today, especially in winter, but was much warmer back in the Cretaceous period. Photo courtesy Kurtis Walsh/www.shutterstock.com

New deadly snake discovered in Asia



The new krait species, now known as *Bungarus suzhenae*. Photo courtesy Dr Li Ding



An illustration portraying a scene from the *Legend of the White Snake* by Xin Wang, from the Chongqing Museum of Natural History.

In 2001, the famous herpetologist Joseph B. Slowinski tragically died from the bite of an immature black and white banded krait, while leading an expedition team in northern Myanmar (Burma). Now, 20 years later, the snake that was responsible for his death has finally been confirmed as being a previously unrecognised species, following an examination of samples collected over recent years from Yingjiang County in China's Yunnan Province.

The new krait species, occurring in southwestern parts of China and northern Myanmar, has been described by a team comprised of Dr Zening Chen of Guangxi Normal University; Shengchao Shi; Dr Li Ding from the Chengdu Institute of Biology at the Chinese Academy of Sciences; Dr Gernot Vogel of the Society for Southeast Asian Herpetology in Germany and Dr Jingsong Shi of the Institute of Vertebrate Palaeontology and Palaeoanthropology at Chinese Academy of Sciences.

Kraits are a group of highly venomous species of snake occurring through southern parts of south-east Asia. Their range extends across from Pakistan across to China and south to Indonesia. They are nocturnal by nature, and primarily hunt other snakes, although they will also prey on other vertebrates, including frogs and lizards.

Named after a snake goddess

The researchers decided to name the new species as *Bungarus suzhenae* or Suzhen's krait, after the mythical figure of Bai Su Zhen (白素贞) – a powerful snake goddess who features in the traditional Chinese story known as the 'Legend of White Snake (白素贞)'. The legend says that, after thousands of years of practicing magic, the white snake Bai Su Zhen transformed herself into a young woman and fell in love with the man called Xu Xian.

Together, the couple ran a hospital, saving many human lives with medicine and magic. However, this love between goddess and

⮝ **The banding and similarity in appearance of these snakes has made them hard to distinguish.** Photo courtesy Mufti Adi Utomo/www.shutterstock.com

human was forbidden by the world of the gods and, eventually, Bai Su Zhen was imprisoned in a tower for eternity. The Chinese regard her as a symbol of true love and good-heartedness as a consequence.

Similar patterning causes confusion

"The black and white banded krait is one of the snakes most similar to the white snake in nature, so we decided to name it after Bai Su Zhen," say the authors. In fact, the actual discovery of Suzhen's krait was inspired by another accident from 2015, when the Chinese herpetologist Mian Hou was bitten by a black and white banded krait in Yingjiang. "It hurt around the wound, and the skin around it turned dark," said the unfortunate scientist, who luckily survived.

⮝ **The banded krait seen here is one of several similar banded species occurring in China.**
Photo courtesy hermawanandik/www.shutterstock.com

A bite proves distinctive

The authors of the present study realised that the bite was different from those of the many-banded krait (*B. multicinctus*), which occur without clear symptoms or pain around the wound. This clue eventually led to the discovery of Suzhen's krait. Since kraits are highly lethal, understanding the diversity that exists within this group as well as their geographical distribution is vital for saving human lives. Clear descriptions of the species concerned, and accurate classification of deadly snakes mean that research on venom, antivenom development and effective snakebite treatment can advance more rapidly.

The new study makes it easier to distinguish between krait species from China and adjacent parts of southeastern Asia. "Three different species of black and white banded krait from China were previously given the same name — many-banded krait, which would hinder appropriate medical treatment," say the scientists. Additionally, they suggest that antivenom for the many-banded krait be reevaluated accordingly.

Further information

Ze-Ning Chen, Sheng-Chao Shi, Gernot Vogel, Li Ding, Jing-Song Shi. **Multiple lines of evidence reveal a new species of Krait (Squamata, Elapidae, Bungarus) from Southwestern China and Northern Myanmar.** *ZooKeys*, 2021; 1025: 35 DOI: 10.3897/zookeys.1025.62305

Breakthrough in our understanding of sex determination in bearded dragons

According to new research carried out at the University of Canberra, bearded dragon embryos can use two different sets of genes to become a female lizard. One of these sets is activated by the sex chromosomes, while the other is activated by high temperatures during development.

A young bearded dragon. Photo courtesy thomascanss/www.shutterstock.com

A young bearded dragon emerges from its egg, with its gender determined by this stage. Photo courtesy MilanSim/www.shutterstock.com

The over-ride system

In many reptiles and fish, the sex of a developing embryo depends on the temperature of the surrounding environment. This phenomenon, called temperature-dependent sex determination (TDSD), was discovered in the 1960s, but the molecular details of how it happens have eluded scientists despite over half a century of intensive research.

Scientists investigated the biochemical pathways required to make a female in this new study by studying the phenomenon in bearded dragons (*Pogona vitticeps*). Male bearded dragons have ZZ sex chromosomes, while females have ZW sex chromosomes. However, hot temperatures can override ZZ sex chromosomes, causing a male lizard to develop as a female.

Researchers Sarah Whiteley and Arthur Georges compared which genes were turned on during development in bearded dragons with ZW chromosomes, compared to ZZ animals exposed to high temperatures. They discovered that initially, different sets of developmental genes are active in the two types of females, but that ultimately the pathways converge to produce ovaries. The findings support other recent research proposing that ancient signalling processes inside the cell help to translate high temperatures into a sex reversal.

Incubation temperature can influence the gender of bearded dragon hatchlings, but it is now known to be not the sole determinant. Photo courtesy Steve Buchus/www.shutterstock.com

The relationship between temperature and gender

This new study is the first to show that there are two ways to produce an ovary in the bearded dragon and bringing us closer to understanding how temperature determines sex. The study also identifies several candidate genes potentially involved in temperature-dependent sex determination.

These findings lay the foundation for future experiments to tease out each gene's role in sensing temperature and directing sexual development. "This new knowledge is bringing us closer to understanding how temperature determines sex, so it is a very exciting time to be in this area of research," adds Sarah Whiteley.

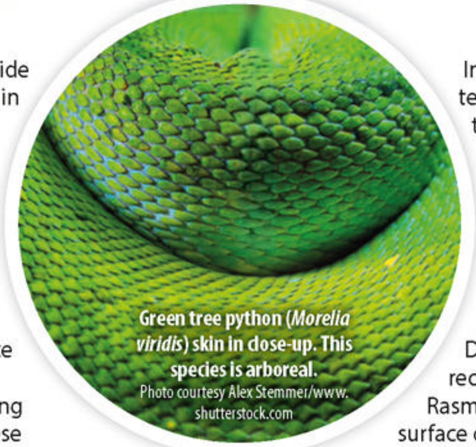
Further information

Sarah L. Whiteley, Clare E. Holleley, Susan Wagner, James Blackburn, Ira W. Deveson, Jennifer A. Marshall Graves, Arthur Georges. **Two transcriptionally distinct pathways drive female development in a reptile with both genetic and temperature dependent sex determination.** *PLOS Genetics*, 2021; 17 (4): e1009465 DOI: 10.1371/journal.pgen.1009465

THE TRUTH REVEALED: YES, SNAKES ARE SLIMY!

The creamsicle morph of the corn snake (*Elaphe guttata*).
Photo courtesy Ermolaev Alexander/www.shutterstock.com

Snakes move in a wide variety of habitats in a number of different ways. Some species slither across the ground, while others climb trees, dive through sand or glide across water. New research is revealing that the surface chemistry of the snake's actual scales varies among species that occur in these different types of terrain. In addition, the findings could have implications for designing durable materials, as well as robots that mimic snake locomotion to cross surfaces that would otherwise be impassable.



Green tree python (*Morelia viridis*) skin in close-up. This species is arboreal.
Photo courtesy Alex Stemmer/www.shutterstock.com

The research began as a collaboration with Woodland Park Zoo in Seattle, explains Dr Tobias Weidner, the project's principal investigator. One of the zoo's biologists told Weidner that not much was known about the chemistry of snake surfaces. "Biologists typically don't have techniques that can identify molecules on the outermost layer of a surface such as a snake scale," he says. "But I'm a chemist — a surface scientist — so I felt I could add something to the picture with my lab's methods."

What makes snakes slimy

As the result of that collaboration, the researchers discovered that land snakes are covered with a lipid layer. This oily layer is so thin — a mere one or two nanometres — that no one had noticed it before! The team also found that the molecules in this layer are disorganised on the snake's back scales but highly organised and densely packed on its belly scales, providing an arrangement that offers lubrication and protection against wear.

"Some people are afraid of snakes because they think they're slimy, but biologists tell them snakes aren't slimy; they're dry to the touch," Weidner says. "That's true, but it's also not true because at the nanoscale level, we found they actually are greasy and slimy, although you can't feel it. They can be described as 'nanoslimy' therefore!"

In the new study, the team wanted to find out if this nanoslimy surface chemistry differs in species adapted to various habitats, explains Mette H. Rasmussen, a colleague of Weidner at Aarhus University in Denmark. Working with recently shed skins, Rasmussen compared the surface chemistry of ground, tree and sand snakes. She used laser spectroscopy and an electron microscopy technique that probes the chemistry of the surface by knocking electrons out of it with X-rays. The project was a collaboration with Dr Joe Baio, based at Oregon State University; Dr Stanislav Gorb at Kiel University and researchers at the U.S. National Institute of Standards and Technology.

Differences dependent on habitat

Rasmussen found that the tree snake has a layer of ordered lipid molecules on its belly, just like the ground snake. But the sand snake, which dives through sand, has an ordered lipid layer on both its belly and back. "From a snake's point of view, it makes sense," she says. "You would like to have this friction reduction and wear resistance on both sides if you're surrounded by a hard contact environment instead of only moving across it."

⮝ An adult leopard snake (*Zamenis situla*) slithering over sharp limestone rock on the Mediterranean island of Malta, without suffering any evident skin injury.
Photo courtesy Wirestock Creators/www.shutterstock.com

⮝ The research focused on shed snake skins of different types. Photo courtesy Joyce Mar/www.shutterstock.com

Next, the researchers want to find out where the lipids come from and to look at variations across other snake species, including those that live in water. They would also like to identify the lipids, though Weidner suspects the chemical makeup of the lipid layer is less important than the organisation and density of the lipid molecules it contains.

Exciting possibilities

The work could have broad applications. "A snake's slithering locomotion requires constant contact with the surface that it's crossing, which poses stringent requirements for friction, wear and mechanical stability," Rasmussen explains. Learning how snakes maintain the integrity of their skin when encountering sharp rocks, hot sand and other challenges could help in the design of more durable materials.

In addition, the researchers say, multiple groups are developing robots that mimic a snake's slithering or sidewinding locomotion and — unlike robots with wheels — can therefore negotiate difficult terrain such as steep, sandy slopes. These groups have recently begun taking into account the microstructure of snake scales, but equally, as this new research reveals, the surface chemistry of the scales is also critical to their performance. Bringing these fields together could one day lead to snakelike robots capable of helping in rescue operations, or even freeing a Mars rover stuck in sand, according to Rasmussen, who presented the findings of this research at a recent meeting of the American Chemical Society.

Types of teeth indicate dietary changes

New research has revealed that the diets of early lizards and snakes, which lived alongside dinosaurs around 100 million years ago, were more varied and advanced than previously thought.

The study, led by the University of Bristol in the UK has revealed that lizards, snakes, and the now-extinct mosasaurs already had developed a full spectrum of diet types during the Cretaceous period, including flesh-eating and plant-based forms.

There are currently some 10,000 living species of lizards and snakes, known collectively as squamates. It was originally understood their great diversity was acquired only after the extinction of dinosaurs, but the findings demonstrate for the first time that squamates had modern levels of dietary specialisation 100 million years ago.

A tokay gecko's teeth. This species can inflict a painful bite. Photo courtesy Reptiles4all/www.shutterstock.com

Unravelling the mystery

Fossils of lizards and snakes are quite rare in the Mesozoic, which represented the age of dinosaurs and reptiles. This could simply be because their skeletons are small and delicate, which made them less likely to be fossilised, or it could show that lizards and snakes were in fact quite rare in the initial stages of their development.

The researchers studied 220 different Mesozoic squamates, made up of lizards, snakes and mosasaurs, which were a group of large, primarily marine reptiles. They measured their jaws and teeth, allocating them to dietary classes by comparison with modern forms. Some have long peg-like teeth and feed on insects, whereas others rely on flat teeth for chopping plant food. Predatory species have sharp, pointed teeth, and snakes have hooked teeth to grasp their prey.

All the fossil forms were allocated to one of eight feeding categories, and then their diversity through time was assessed. To the researchers' surprise, it turned out that the rather scarce Cretaceous squamates included examples of all these modern feeding types.

Starting out as insect-eaters

"We don't know for sure how diverse squamates were in the Cretaceous," says Dr Jorge Herrera-Flores, who is now a Research Fellow at the National Autonomous University of Mexico. "But we do know they had already achieved the full modern diversity of feeding modes by 100 million years ago, during the middle of the Cretaceous. Before that, squamates had already existed for more than

Relatively few snakes feed primarily on insects today. The rough green snake (*Opheodrys aestivus*) from North America is an exception.
Photo courtesy Steve Bower/www.shutterstock.com

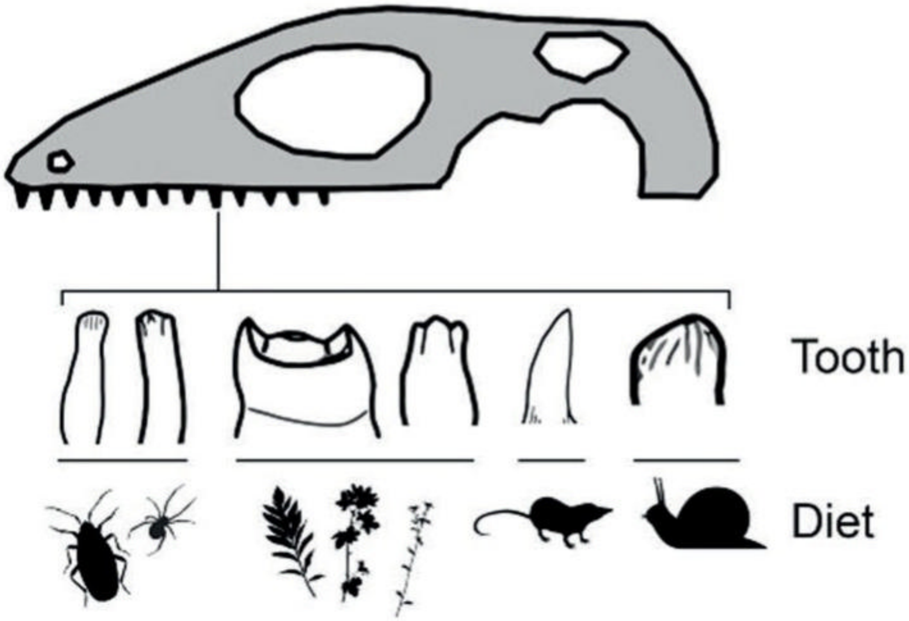
The Cretaceous was a period of great ecological development, and although it ended 66 million years ago with the extinction of the dinosaurs and many other life forms, including mosasaurs, squamates have survived though to the present day.
Photo courtesy ronniejcmc/www.shutterstock.com

The early lizards were predominantly insect-eaters, as reflected by their dentition, just like some of their descendants such as this blue-eyed anglehead lizard (Gonocephalus liogaster) today. Photo courtesy Chattraphas Pongcharoen/www.shutterstock.com

100 million years, but they seemed to have been mainly insect-eaters up to that point."

"Studying teeth and jaws provides excellent insights into dietary and ecological variety," adds Dr Tom Stubbs, Senior Research Associate at the University of Bristol School of Earth Sciences. "Fossil teeth and jaws give us the best insight into squamate evolution in the past. It would be easy to read the fossil record wrongly because of incomplete preservation. However, more fossil finds could only increase the number of feeding modes we identify in the Cretaceous, not reduce them."

The explanation for this early rush of dietary experimentation may be related to diversification in other areas. For instance, at this point in the Cretaceous, flowering plants had just begun to flourish and were already transforming ecosystems on land, while squamates also prevailed in the oceans.



Tooth shape is related to diet. Artwork courtesy Tom Stubbs

A major ecological boom

"The Cretaceous terrestrial revolution made forests more complex," explains Professor Michael Benton, Professor of Vertebrate Palaeontology at the School of Earth Sciences. "The new flowering plants provided opportunities for insects and other creepy crawlies to feed on leaves, pollen and nectar, and to hide in the canopy. It's likely this burst of diversity gave a stimulus to mammals, birds and squamates, all of which diversified about this time, probably feeding on the insects, spiders and other bugs, as well as on the new plant food."

This new study does not provide the reason as to why squamates are so diverse today – proving to be nearly as varied as birds. However, it shows that their ancestors had already explored all the likely feeding niches 100 million years ago, even before the dinosaurs had died out.

Further information

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Tortoises hatch with a natural attraction to faces

This new study provides the first evidence of the tendency for solitary animals to approach face-like shapes at the beginning of life, a preference only previously observed in social species such as human babies, chicks and monkeys.

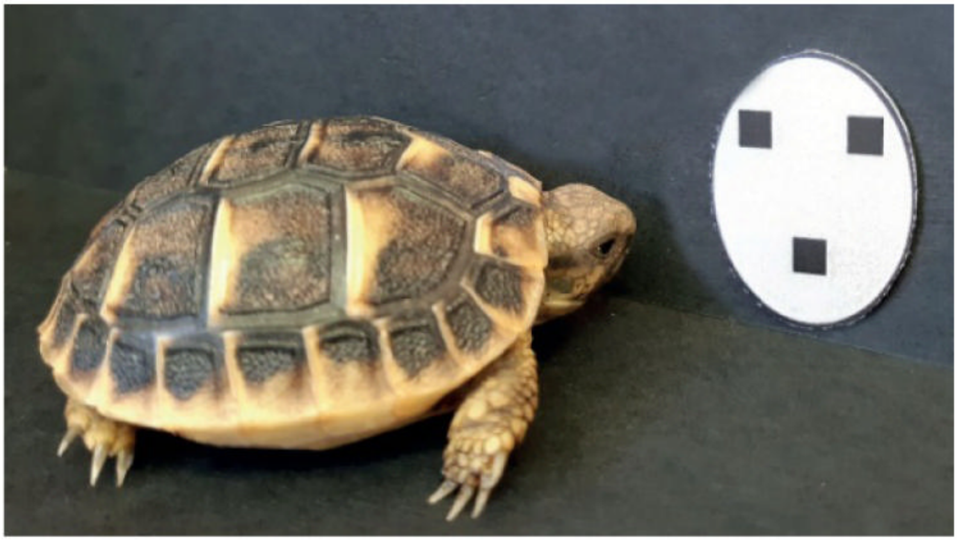
The researchers tested the reactions of hatchlings of five different species of tortoise to different patterned stimuli, made up of a series of blobs. They found that the tortoises consistently moved to areas with the 'face-like' configuration — containing three blobs arranged in an upside-down triangle shape. The findings suggest that this early behaviour most likely evolved in the common ancestors of mammals, reptiles and birds more than 300 million years ago.

Previously thought to be linked to parental care

Dr Elisabetta Versace from London's Queen Mary University explains: "Researchers have previously observed this spontaneous attraction to faces in social animals such as humans, monkeys and chicks. Since all these species require parental care, it was thought this early adaptation was important for helping young animals respond to their parents or other members of the same species. However, now we have shown that this behaviour is also found in solitary tortoise hatchlings, this suggests that it may have evolved for another reason."

Tortoises were hatched and kept away from any animal or human faces from birth until the start of the test. Each individual was then placed in the middle of a rectangular space divided into four areas, containing either a face-like or control stimuli. The researchers analysed the preference of hatchlings for face-like stimuli by recording the first area that the animal entered during the experimental period.

➤ **It has now been revealed that tortoises like people's faces.** Photo courtesy Maridav/www.shutterstock.com



➤ **A tortoise hatchling next to one of the face-like representations used in the study.** Photo courtesy Gionata Stancher.

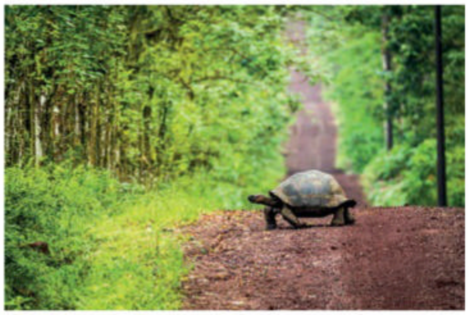
➤ **It obviously helps pet tortoises to recognise their owners, as they are likely to be given food by them.**
Photo courtesy MintImages/www.shutterstock.com

Learning from others

Unlike birds and mammals, tortoises are solitary species – they have no post-hatching parental care and do not form social groups as adults. Previous research has even shown that tortoise hatchlings ignore or avoid members of the same species in early life.

Silvia Damini from the University of Trento in Italy says: "It is possible that this preference for face-like stimuli enhances learning from living animals in both social and solitary species from the early stages of life. In fact, other animals can provide information on important environmental factors, such as the availability of resources."

Gionata Stancher, Head of the Tortoise Sanctuary Sperimentarea (Fondazione Museo Civico Rovereto, Italy) where the experiments were conducted, adds: "Being able to recognise and respond to cues associated with other living animals could help young animals acquire information vital for their survival."



➤ **Tortoises are solitary by nature, from the point of hatching onwards.** Photo courtesy nwdph/www.shutterstock.com

Further information

Elisabetta Versace, Silvia Damini, Gionata Stancher. **Early preference for face-like stimuli in solitary species as revealed by tortoise hatchlings.** *Proceedings of the National Academy of Sciences*, 2020; 202011453 DOI: 10.1073/pnas.2011453117

Turtles locate an invisible ocean corridor

Loggerhead turtles in the northern Pacific ocean have proven the words of *Lord of the Rings'* author J.R.R. Tolkien that "Not all those who wander are lost ... " to be true. They undertake a little-understood journey that unfolds over thousands of miles and lasts for potentially two decades or more. Now, a Stanford University-led study illuminates the secrets of their epic migration and their so-called 'lost years' spent between where they hatch on the beaches of Japan and their subsequent re-emergence years later in foraging grounds off the coast of Baja California.

This new study provides evidence for intermittent passages of warm water that allow sea turtles to cross otherwise inhospitably cold ocean barriers. Those involved in this research hope the findings could help to inform the design of conservation measures to protect sea turtles and other migratory sea creatures amid climatic changes that are altering their movements.

A loggerhead turtle swimming in open water. Photo Schnapps2012/www.shutterstock.com

Much still remains to be learnt about where young loggerhead turtles spend their early years of life. Photo courtesy aleespinolac/www.shutterstock.com

"For decades, our ability to connect the migratory dots for this endangered species has remained elusive," admits Dana Briscoe, who was a research associate at the Stanford Woods Institute for the Environment during the research and now works at the Cawthron Institute, New Zealand's largest independent marine science organisation. "This work builds on the backbone of exceptional research about these 'lost years,' and for the first time ever we are excited to provide evidence of a 'thermal corridor' to explain a longstanding mystery surrounding one of the ocean's greatest migrants."

⮝ **Loggerheads and other marine turtles cover huge distances in the world's oceans, and are not easy to study as a result, without considerable technological support.** Photo courtesy William Bradberry/www.shutterstock.com

Endangered migrants

Wildlife seekers thrill to the sight of sea turtles, but ships, fishing nets and other perils have been less kind to this group of aquatic reptiles, especially over recent centuries. The International Union for Conservation of Nature (IUCN) now lists six of today's seven surviving sea turtle species as critically endangered, endangered or vulnerable.

Despite scientific advancements in understanding the key habitats where they are to be found, we still know precious little about the movement of turtles and other long-lived sea creatures between disparate locations. This knowledge gap makes it impossible to assess and protect these species as effectively as possible.

The researchers wanted to know how and why some loggerheads travel to the western coastline of North America while others remain in the central Pacific Ocean. How is it that some sea turtles - a group which are highly sensitive to the temperature of their environment - can cross a frigid zone called the Eastern Pacific Barrier between the two ocean regions that normally stops most creatures in their tracks?

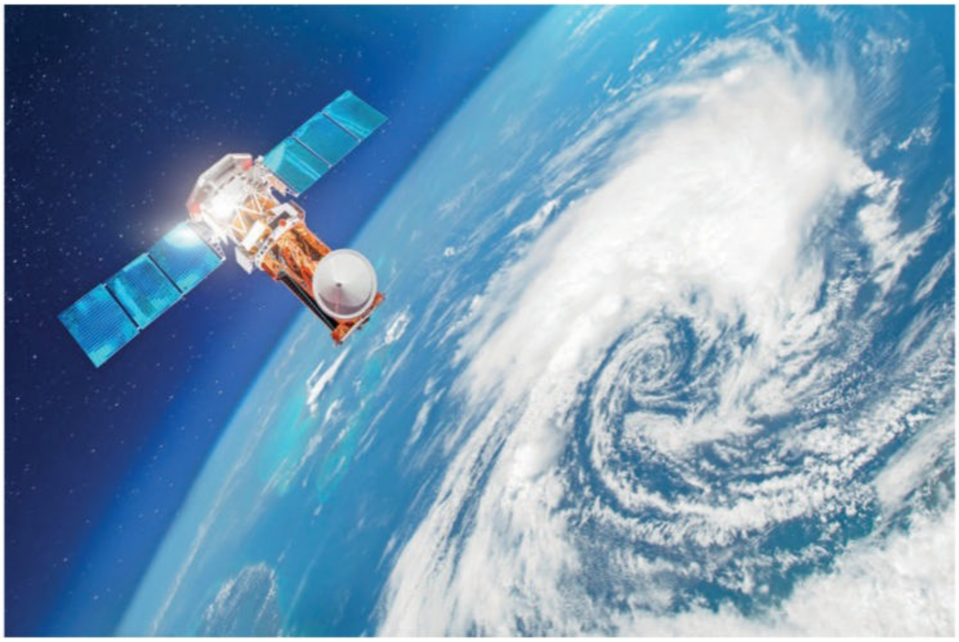
In order to unlock that mystery, the researchers created the largest dataset on satellite-tagged loggerhead sea turtles ever compiled, employed sophisticated remote-sensing oceanographic techniques and collected one of the first detailed records of sea turtle ageing and stable isotope testing - a bone analysis that can be used to provide information about an animal's life. The work relied upon decades of research by the international team of scientists.

How the detective work was undertaken

They started by looking at a 15-year study tracking the movements of more than 200 turtles tagged with satellite tracking devices. Six of the turtles caught the researchers' attention because, unlike their peers, they made distinct movements toward the North American coast. Adding to the intrigue, the "sentinels," as the researchers called them, made their journey during the early spring months. A look at remotely sensed ocean conditions for the time period showed that the farthest-roaming of the sentinels swam through water significantly warmer than their peers had confronted on their travels.

A bigger picture analysis involved identifying the years that loggerheads arrived in Baja California by measuring stable isotope "fingerprints" in the bones of sea turtles stranded on beaches there. Because like us, turtles are what they eat, so these stable isotope signatures can reveal when the turtles transitioned from the open sea to the coast. The analysis showed significantly greater annual numbers of eastward-bound sea turtles during warm ocean conditions.

Bone tests involving dead loggerhead turtles that had washed up on the beach formed a vital part of the research.
Photo courtesy Trevor Charles Graham/www.shutterstock.com



⮝ Satellite tracking data has played a significant part in unlocking the mystery.
Photo courtesy aapsky/elements of the image furnished by NASA/www.shutterstock.com

The likely cause, according to the researchers: the development of a "thermal corridor" from unusually warm sea surface temperatures due to the El Niño effect and other intermittent ocean warming conditions that allowed the turtles to cross the Eastern Pacific Barrier to coastal foraging grounds.

The corridor was present during the late spring and summer, and was also preceded by early warming of temperatures in the months before it opened. Such anomalous conditions, especially if sustained for several months, may provide key environmental cues to sea turtles and other animals concentrated

A young loggerhead sea turtle entangled in a fishing net. Photo courtesy Agami Photo Agency/www.shutterstock.com

in the eastern edge of the central Pacific that the thermal corridor is opening. Studies combining data from loggerhead aerial surveys, 'at sea' sightings, stranding records and tissue samples supported this hypothesis.

A dangerous trend

The phenomenon may be part of a trend. As the planet undergoes climate changes, locations once considered impassable obstacles to species movements, like the Eastern Pacific Barrier, are being redefined. This, in turn, is shifting the distributions and migratory pathways of creatures ranging from sea birds to white sharks and presenting new conservation challenges.

For the north Pacific loggerhead, the trend could mean a higher risk of becoming so-called 'bycatch' (being caught unintentionally in nets set to catch fish) off the Baja California coast and other potentially important North American foraging grounds, including the Southern California Bight. The study provides important insights, such as an understanding of how animal movements relate to climate variation, that could help predict when sea turtles and other protected species would be vulnerable to such threats.

The researchers caution that their multi-year dataset represents only a snapshot of an important developmental period for sea turtles. The small number of turtles that moved into the eastern North Pacific limits the ability to fully test the study's hypothesis under varying conditions. To do that, the researchers call for more satellite tagging and stable isotope studies of turtle bones in this region.

"Understanding how and why species like the north Pacific loggerhead move among habitats is crucial to helping them navigate threats," says Larry Crowder, the Edward Ricketts Provostial Professor at Stanford University's Hopkins Marine Station. "Emerging technologies and analyses can help to illuminate these journeys going forwards."

⮝ The El Niño effect has widespread impacts on ocean currents and storm patterns, as shown here in the northern Pacific, off the coast of San Diego, at the northern end of Baja California. Photo courtesy John Sullivan/www.shutterstock.com

Further information

Dana K. Briscoe, Calandra N. Turner Tomaszewicz, Jeffrey A. Seminoff, Denise M. Parker, George H. Balazs, Jeffrey J. Polovina, Masanori Kurita, Hitoshi Okamoto, Tomomi Saito, Marc R. Rice and Larry B. Crowder. **Dynamic Thermal Corridor May Connect Endangered Loggerhead Sea Turtles Across the Pacific Ocean.** *Front. Mar. Sci.*, 08 April 2021 DOI: 10.3389/fmars.2021.630590

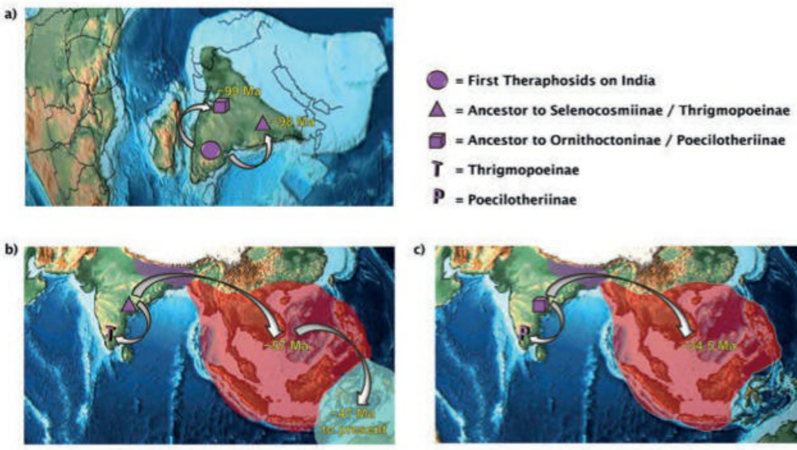
Why do tarantulas have such a wide distribution?

A subadult female Mexican orange-knee tarantula (*Brachypelma hamorii*) is an impressive sight. Photo courtesy Ernie Cooper/www,shutterstock.com

Tarantulas are amongst the most notorious of all spiders, thanks in part to their large size, and their vibrant colours in many cases. They also have a very wide range across the world's continents. But one thing most people don't know is that tarantulas are not wide-ranging spiders. Females and their young rarely leave their burrows and only mature males will wander to seek out a mate. How then did such a sedentary spider come to inhabit six out of seven of today's continents?

An international team of researchers, including Carnegie Mellon University's Saoirse Foley, based in the US city of Pittsburgh in Pennsylvania, set out on an ancestral investigation to find the answer to this question. They looked initially to the

⮝ An Indian ornamental tarantula (*Poecilotheria regalis*). Photo courtesy fivespots/www.shutterstock.com



a)
~99 Ma
~98 Ma
● = First Theraphosids on India
▲ = Ancestor to Selenocosmiinae / Thrigmopoeinae
■ = Ancestor to Ornithoctoninae / Poecilotheriinae
T = Thrigmopoeinae
P = Poecilotheriinae
b)
T
~57 Ma
~47 Ma to present
c)
P
~34.5 Ma

⮝ Two independent tarantula lineages emerged from India. Map credit: https://dinosaurpictures.org/, 2021.

transcriptomes, the sum of all the transcripts from the genetic material mRNA, of many tarantulas and other spiders from different time periods.

Where they originated

They then used the transcriptomes to build a genetic tree of spiders and time-calibrated their tree with fossil data. Tarantula fossils are extremely rare, but the software used in the study managed to estimate the ages of older tarantulas relative to the ages of fossils from other spiders.

They found that tarantulas are representatives of an ancient group, first emerging in the area of land now considered the Americas about 120 million years ago during the Cretaceous period.

At that time, South America would have been attached to Africa, India and Australia as part of the Gondwana supercontinent. The spiders ultimately reached their present destinations thanks to continental drift when these continents split off, but with a few interesting variants.

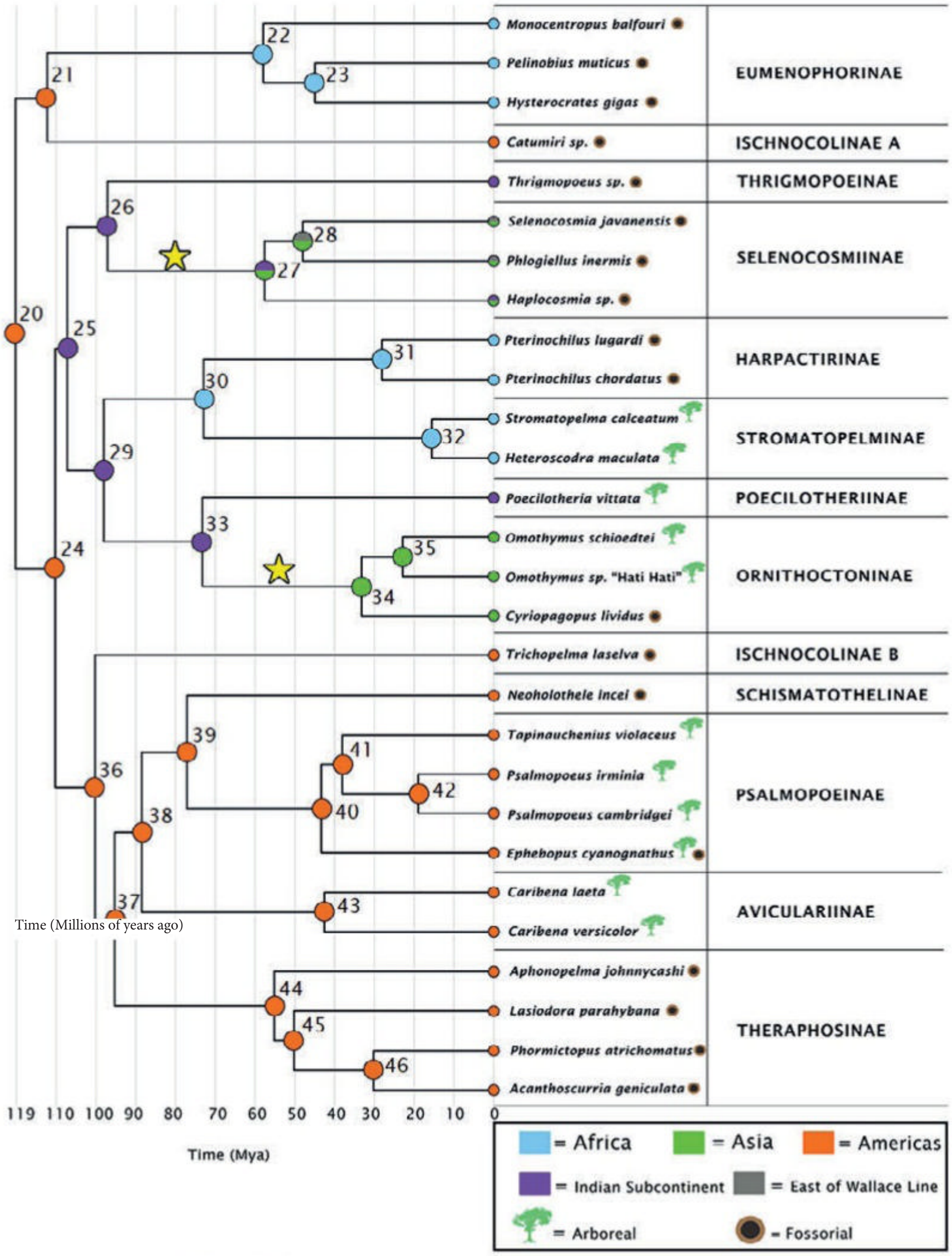
Surprises in Asia

For example, the nature of their entry into Asia suggests tarantulas may also be surprisingly proficient dispersers. The researchers were able to establish two separate lineages of tarantulas that diverged on the Indian subcontinent before it crashed into Asia, with one lineage being predominantly ground dwelling and the other mainly arboreal. They found that these lineages colonised Asia about 20 million years apart. Surprisingly, the first group that reached Asia also managed to cross the Wallace Line, a boundary between Australia and the Asian islands where many species are found in abundance on one side and rarely or not at all on the other.

“Previously, we did not consider tarantulas to be good dispersers. While continental drift certainly played its part in their history, the two Asian colonisation events have led us to reconsider this belief. The microhabitat differences between those two lineages also suggest that tarantulas are experts at exploiting ecological niches, while simultaneously displaying signs of niche conservation, meaning they do not diverge significantly from their past ecological characteristics,” says Foley.

Further information

Saoirse Foley, Henrik Krehenwinkel, Dong-Qiang Cheng, William H. Piel. **Phylogenomic analyses reveal a Gondwanan origin and repeated out of India colonizations into Asia by tarantulas (Araneae: Theraphosidae).** *PeerJ*, 2021; 9: e11162 DOI: 10.7717/peerj.11162


Monocentropus balfouri
Pelinobius muticus
Hysterocrates gigas
EUMENOPHORINAE
Catumiri sp.
ISCHNOCOLINAE A
Thrigmopoeus sp.
THRIGMOPOEINAE
Selenocosmia javanensis
Phlogiellus inermis
Haplocosmia sp.
SELENOCOSMIINAE
Pterinochilus lugardi
Pterinochilus chordatus
HARPACTIRINAE
Stromatopelma calceatum
Heteroscodra maculata
STROMATOPELMINAE
Poecilotheria vittata
POECILOTHERIINAE
Omothymus schioedtei
Omothymus sp. "Hati Hati"
Cyriopagopus lividus
ORNITHOCTONINAE
Trichopelma laselva
ISCHNOCOLINAE B
Neoholothele incei
SCHISMATOTHELINAE
Tapinauchenius violaceus
Psalmopoeus irminia
Psalmopoeus cambridgei
Ephebopus cyanognathus
PSALMOPOEINAE
Caribena laeta
Caribena versicolor
AVICULARIINAE
Aphonopelma johnnycashi
Lasiodora parahybana
Phormictopus atrichomatus
Acanthoscurria geniculata
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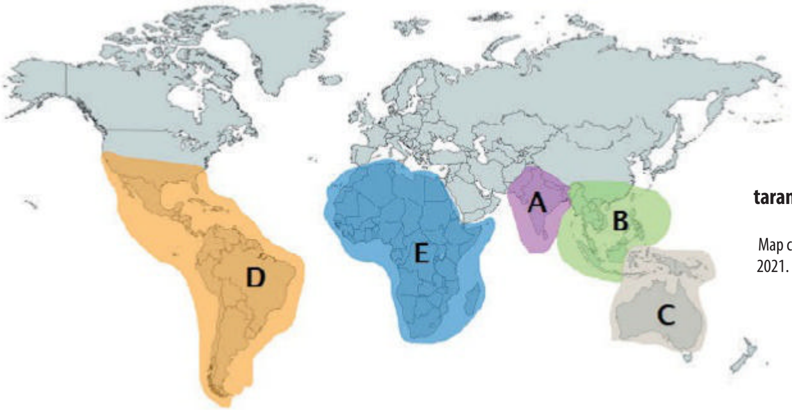


Ancestral ranges of tarantulas as estimated by the research team.

Map credit: https://mapchart.net/, 2021. Licensed under CC BY-4.0 SA.

Egg colour competition

A pair of opposing evolutionary forces explain the presence of the two different coloured egg masses of spotted salamanders at ponds in Pennsylvania, according to a new study led by a Penn State biologist. Understanding the processes that maintain biological diversity in wild populations is a central question in biology and may allow researchers to predict how species will respond to global change.

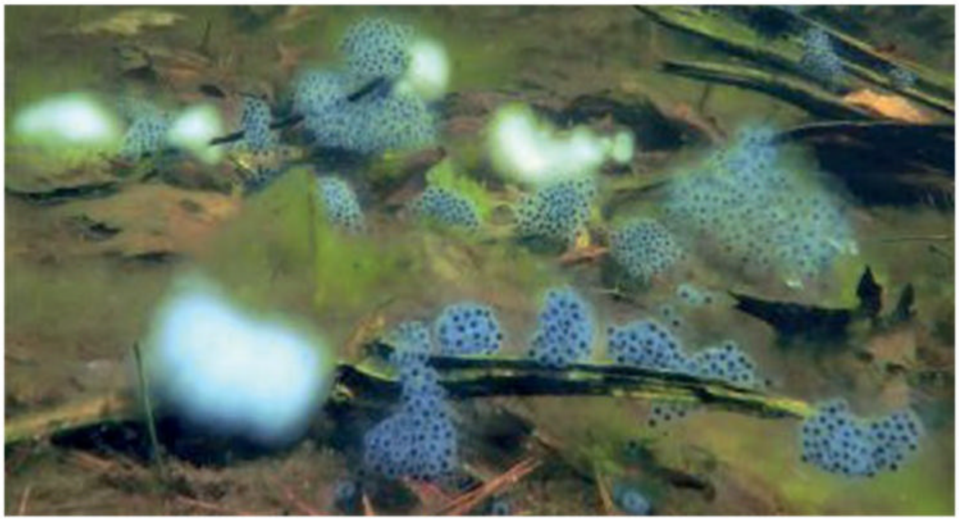
Spotted salamander. Photo courtesy Matt Jeppson/ www.shutterstock.com

Differences in colour

Spotted salamanders (*Ambystoma maculatum*) are a widespread species that occurs across the eastern United States and return to temporary ponds in the spring to reproduce. Female salamanders lay their eggs in clumps called egg masses, which are either opaque white or completely clear. Females lay the same colour egg masses throughout their life, but it is unclear what causes the different colouration, or if either of these colours confers an advantage to the eggs—for example if one colour is less obvious to predators.

"We usually think of evolution operating over hundreds or thousands of years, but in reality, the evolutionary processes at play in a system can influence each generation of animals," explains Sean Giery, Eberly Postdoctoral Research Fellow at Penn State and leader of the research team. "In this study, we looked again at ponds that were originally studied in the early 1990s, and this gave us a unique opportunity to explore the evolutionary processes shaping the frequencies of the two egg mass colour types, or morphs, that we see today."

⮝ **Courtship in a pair of spotted salamanders.** Photo courtesy Matt Jeppson/www.shutterstock.com



⮝ **Two opposing evolutionary forces help explain why we see two different colours of spotted salamander egg masses in ponds in central Pennsylvania, according to a new study. Egg masses are either completely clear or opaque white.** Photo courtesy Mark Urban, University of Connecticut.

Past and present

Giery resurveyed a network of 31 ponds in central Pennsylvania, noting the colour of salamander egg masses as well as the environmental characteristics present at each pond. The ponds were originally surveyed in 1990 and 1991 by then Penn State Professor of Biology Bill Dunson and his students. The research team found that salamander population sizes and pond chemistry remained stable over the last three decades. When averaged across the region, the overall frequency of each egg colour morph also remained the same — about 70% were white egg masses in both 1990 and 2020 — but in many cases, the frequency within individual ponds had changed drastically.

“At the level of the individual ponds, it’s an extremely dynamic system,” says Giery. “They don’t just reach one frequency and stay there. By focusing on individual ponds rather than just the region as a whole, we could tease apart what is driving these changes in population frequencies. In this case, we found two opposing evolutionary processes — selection and drift.”

The researchers uncovered strong signs of an evolutionary process called genetic drift, which can result in morph (colour variant) frequencies changing due to chance. In small populations, drift is more likely to have a major effect, for example with one of the morphs disappearing entirely. As expected due to drift, the researchers found that the frequencies of each morph changed more dramatically in ponds with fewer egg masses.

“However, none of the ponds completely shifted to one morph or the other, which suggests something else might also be going on,” explains Giery. “We found that ponds at the extremes in the 1990s — with a high frequency of clear or a high frequency of white egg masses — became less extreme, shifting toward the overall mean for the region. This supports the idea that ‘balancing selection’ is operating in this system.”

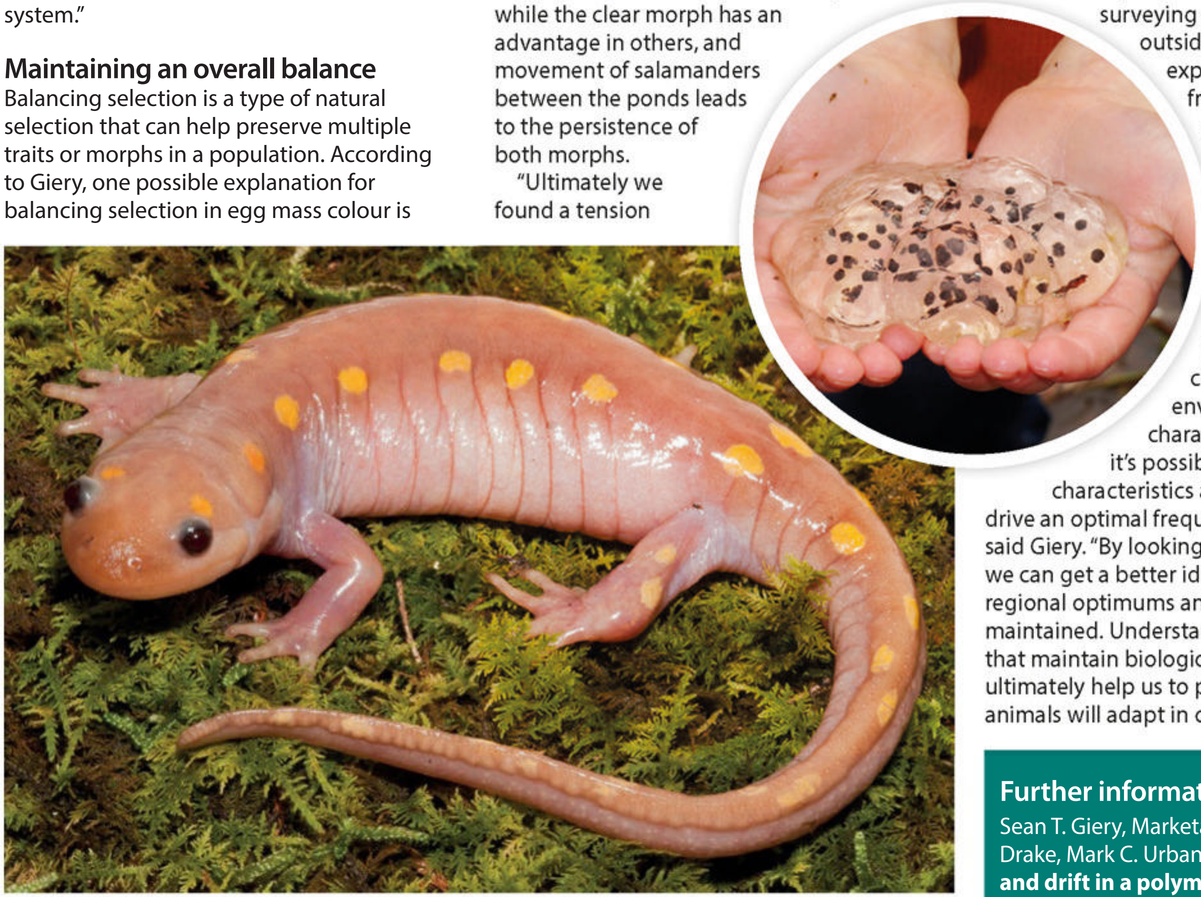
⮝ These salamanders live in forested areas, returning to neighbourhood ponds where they spawn in the spring.
Photo courtesy Mike Wilhelm/www.shutterstock.com

Maintaining an overall balance

Balancing selection is a type of natural selection that can help preserve multiple traits or morphs in a population. According to Giery, one possible explanation for balancing selection in egg mass colour is that the rare morph in a pond — regardless of the actual colour — has an advantage, which would lead to the rare morph becoming more common. Another possibility is that the white morph has an advantage in some ponds while the clear morph has an advantage in others, and movement of salamanders between the ponds leads to the persistence of both morphs.

“Ultimately we found a tension between these two evolutionary processes, with genetic drift potentially leading to a reduction of diversity in this system, and balancing selection working to maintain it,” adds Giery. The researchers are currently surveying egg masses in ponds outside of Pennsylvania to explore if morph frequencies differ in other regions and whether these evolutionary processes operate in the same way over a larger scale.

“Although we did not find a relationship between egg mass colour and environmental characteristics in this study, it’s possible that environmental characteristics at a larger scale might drive an optimal frequency for each region,” said Giery. “By looking at a much larger scale, we can get a better idea of whether there are regional optimums and how they are maintained. Understanding the processes that maintain biological diversity may ultimately help us to predict how wild animals will adapt in our changing world.”

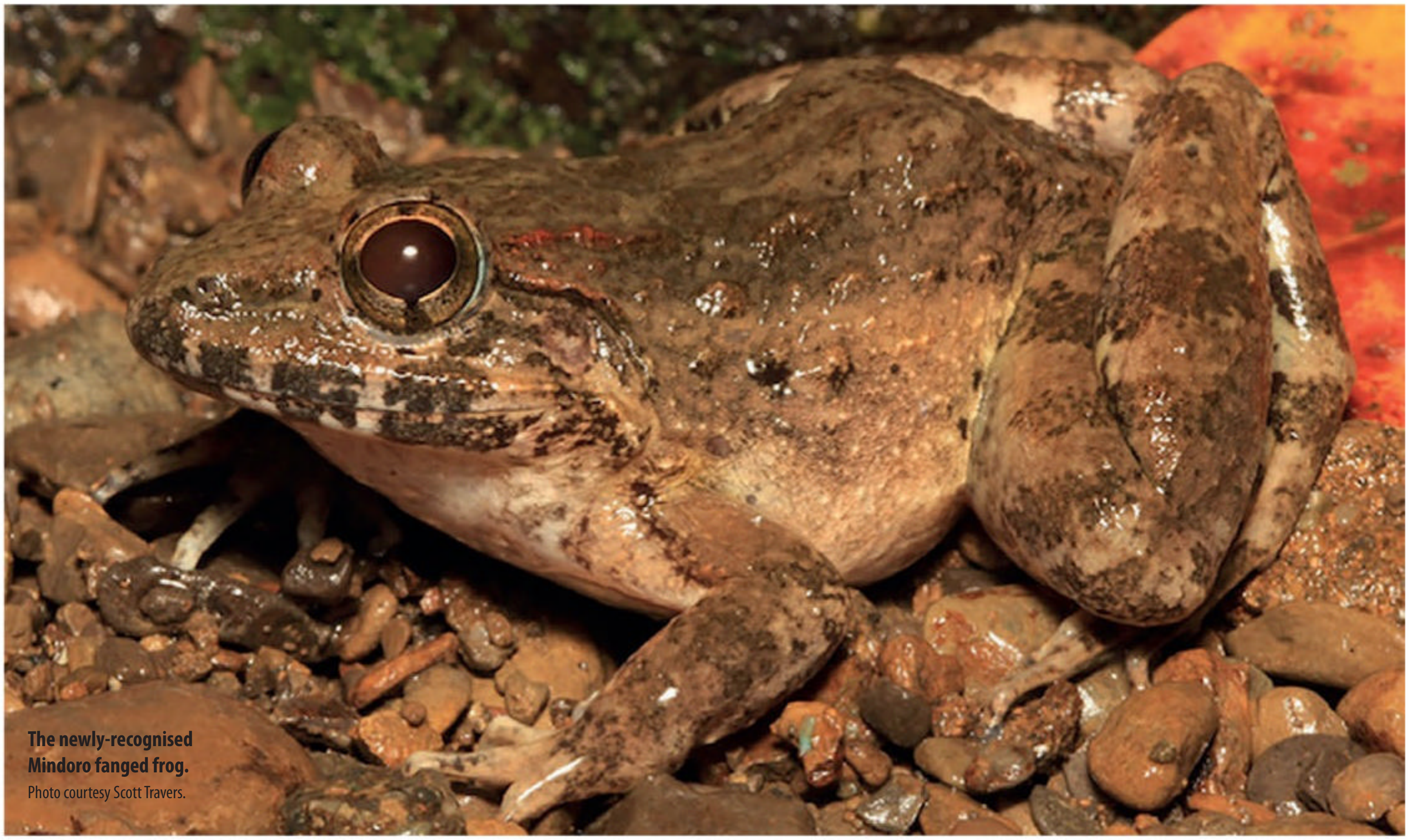


⮝ Occasional albino spotted salamander turn up in the wild, but this colour morph is not linked directly to the colour of the spawn bundles. Photo courtesy Nathan A Shephard/www.shutterstock.com
Inset: A mass of clear spawn of the spotted salamander in close-up. Photo courtesy Matt Jeppson/www.shutterstock.com

Further information

Sean T. Giery, Marketa Zimova, Dana L. Drake, Mark C. Urban. **Balancing selection and drift in a polymorphic salamander metapopulation.** *Biology Letters*, 2021; 17 (4) DOI: 10.1098/rsbl.2020.0901

NEW FANGED FROG FOUND


The newly-recognised Mindoro fanged frog. Photo courtesy Scott Travers.

Researchers at the University of Kansas (KU) have described a new species of fanged frog from the Philippines that is almost indistinguishable from another species found on a neighbouring island, except for its unique mating call and key differences in its genome (or DNA).

"This is what we call a cryptic species because it was hiding in plain sight in front of biologists for many, many years," explains Mark Herr, from the KU Biodiversity Institute and Natural History Museum and Department of Ecology & Evolutionary Biology. "Scientists for the last 100 years thought that these frogs were just the same species as those on a different island in the Philippines because they couldn't tell them apart physically, in terms of their appearance.

The Philippines are a large group of some 7640 islands lying off the coast of Southeast Asia, which are recognised for their biodiversity. Map courtesy Poppartic/www.shutterstock.com

Detailed investigations reveal key differences

"We ran a bunch of analyses—and these frogs do indeed look identical to the naked eye, but they are genetically isolated. We also found marked variations in their mating calls. They sound quite different. So, it was a case of using acoustics to determine that this was distinctive new species, relying also on the new genetic information."

Genetic samples of the new frog, now known scientifically as *Limnonectes beloncioi* (or commonly as the Mindoro fanged frog), were collected years ago by KU scientists working in the field on Mindoro Island but they were not analysed until recently. As a result of its striking physical similarity to a fanged frog on the island of Palawan, called Acanth's fanged frog (*L. acanthi*), it had just been assumed they were in fact the same species.

"You can look at two different things, but to the human eye, they might seem the same without intensive investigation," Herr says. "So, we took a bunch of measurements of hundreds of these frogs—how long their digits were specifically, how wide the tip of their toe was, the length of one specific segment of their leg, the diameter of their eye—in order to compare populations statistically, even if we thought they look the same.

"We ran statistical analyses on body shape and size, including a principal component analysis which uses all the measurements at once to compare their appearances. After all that, just like the scientists before us, we found nothing to differentiate the frogs, based on the shape of their bodies and their size!"

When these species separated

However, because the fanged frogs inhabit islands separated by a large stretch of sea, the researchers had doubts they could be the same species, in part because they had different-sounding calls. They then decided to analyse the frogs' genomes, and determined the Mindoro form qualified as a distinct species on these grounds.

"We ran genetic analyses of these frogs

Habitat of the the newly-recognised species on Mindoro island. Photo courtesy o0hyperblaster/www.shutterstock.com

Fanged frogs are widely distributed across Southeast Asia. This species is *Limnonectes macrodon*, from the island of Java. Photo courtesy W. A. Djatmiko (Wie146)/Wikipedia.

using some specific genetic markers, and we also used a molecular clock model just to get a very basic estimate how long we thought that these frogs may have been separated from one another," Herr explains.

"We found they're related to each other, they are each other's close relatives, but also discovered that they'd been separate for between two to six million years—it's a really long time for these frogs. And it's very interesting that they still look so similar but sound different."

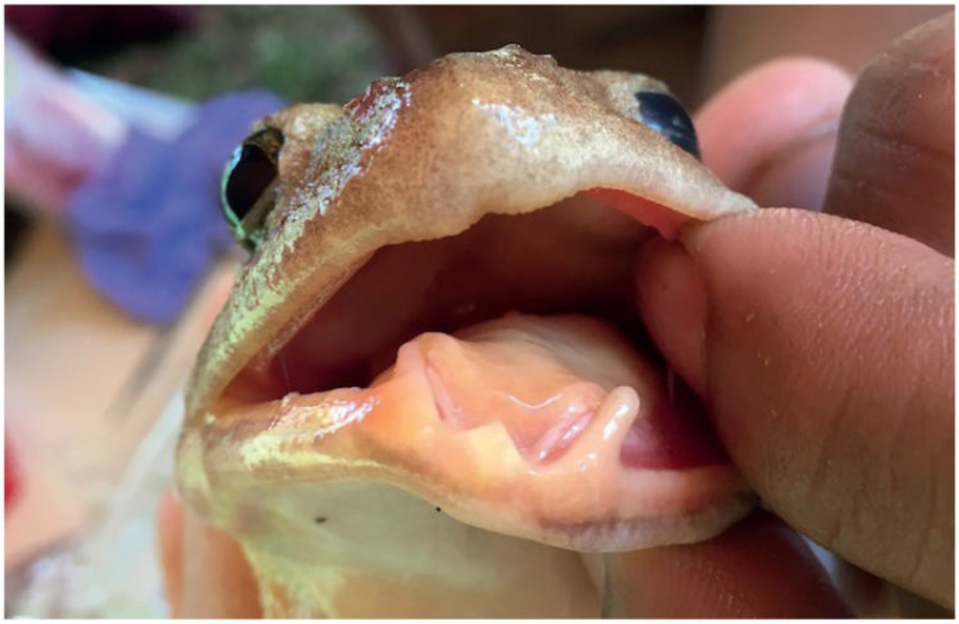
Mark Herr specialises in studying the many species of fanged frog across Southeast Asia, where he's carried out extensive fieldwork. He said the frogs' fangs are most likely used in combat to gain access to prime mating sites and also to protect themselves from predators.

Instinctive caution

The Mindoro fanged frog is found in streams and sometimes hunted by people for food. This amphibian's characteristic call, different from Acanth's fanged frog, proved difficult for researchers to record.

"These frogs were really wary of us when we were out there with our sound recorders trying to get recordings of their calls—that was a really tough aspect. We were lucky that we had people over many years who had previously been there and had recorded both of these frogs on Palawan and Mindoro.

"So we had good recordings from the two islands, and that's kind of rare anyway with this group of fanged frogs, because people eat them. They call at night, but the second a flashlight or human voice wanders into the equation, they're just going to take off because they know that they can be killed by people," Herr adds.



The giant Luzon fanged frog (*Limnonectes macrocephalus*), found on the Philippine island of Luzon, has fangs similar to the Mindoro species. Photo courtesy Rafe Brown.

His description of the Mindoro fanged frog continues a long tradition of KU field research into the herpetological biodiversity of the Philippines and Southeast Asia, according to Rafe Brown, professor of ecology & evolutionary biology and curator-in-charge of the Herpetology Division of the Biodiversity Institute and Natural History Museum.

Overturning the lessons of the past

"Mark's discovery reinforces something we've learned over and over through the years—things we thought we knew, combined with new information, emerge to teach us something completely unexpected," says Brown. "A century ago, KU professor Edward Taylor identified the Mindoro Island population as Acanth's fanged frog, the same species that he had named a few years before from Palawan Island—an arrangement that made very little sense.

"Zoom forward a century, and we find with new technology, genetic information and bio-acoustic (sound) data that the two islands' populations are actually very well-differentiated, as we would expect. But not morphologically, in terms of appearance; their physical characteristics have not diverged. This is a case in which the formation of species has not been accompanied by morphological differentiation—a situation described by zoologists as so-called 'cryptic speciation.'"

Further information

Mark W. Herr, Johana Goyes Vallejos, Camila G. Meneses, Robin K. Abraham, Rayanna Otterholt, Cameron D. Siler, Edmund Leo B. Rico, Rafe M. Brown. **A New, Morphologically Cryptic Species of Fanged Frog, Genus *Limnonectes* (Amphibia: Anura: Dicroglossidae), from Mindoro Island, Central Philippines.** *Ichthyology & Herpetology,* 2021; 109 (1) DOI: 10.1643/h2020095

Big bumblebees begin foraging early

Larger bumblebees are more likely to go out foraging in the low light of dawn, according to new research. Scientists from the University of Exeter in southwest England used RFID—similar to the technology used for contactless card payments—to monitor when bumblebees of different sizes left and returned to their nest.

Photo courtesy Sergei Mironenko/www.shutterstock.com

Out and about

The biggest bees, and some of the most experienced foragers (measured by number of trips that they made), were the most likely to leave in low light.

Bumblebee vision is poor in low light, however, so flying at dawn or dusk raises the risk of getting lost or being eaten by a predator. Nevertheless, the bees benefit from extra foraging time and fewer competitors for pollen following this routine in the early morning.

"Larger bumblebees have correspondingly bigger eyes than their smaller-sized relatives as well as many other bees, and they can therefore see better in dim light," explains researcher Katie Hall. "We might expect all bumblebee foragers to leave the colony and set off as soon as there is enough light to allow them to fly. But in fact, colonies seem to regulate the start of foraging.

Striking the right balance

"There is a balance of risks and rewards when foraging in low light—and most bees wait for higher light levels when they can see better and fly faster, with less risk of predation or getting lost and running out of energy. Our findings that more experienced bees are increasingly likely to fly in lower light suggests that knowledge of food locations helps them navigate safely."

The study tracked the bees' behaviour over five days during warm periods of the flowering season. Only a small proportion of foragers left the colony at dawn when light levels were below 10 lux.

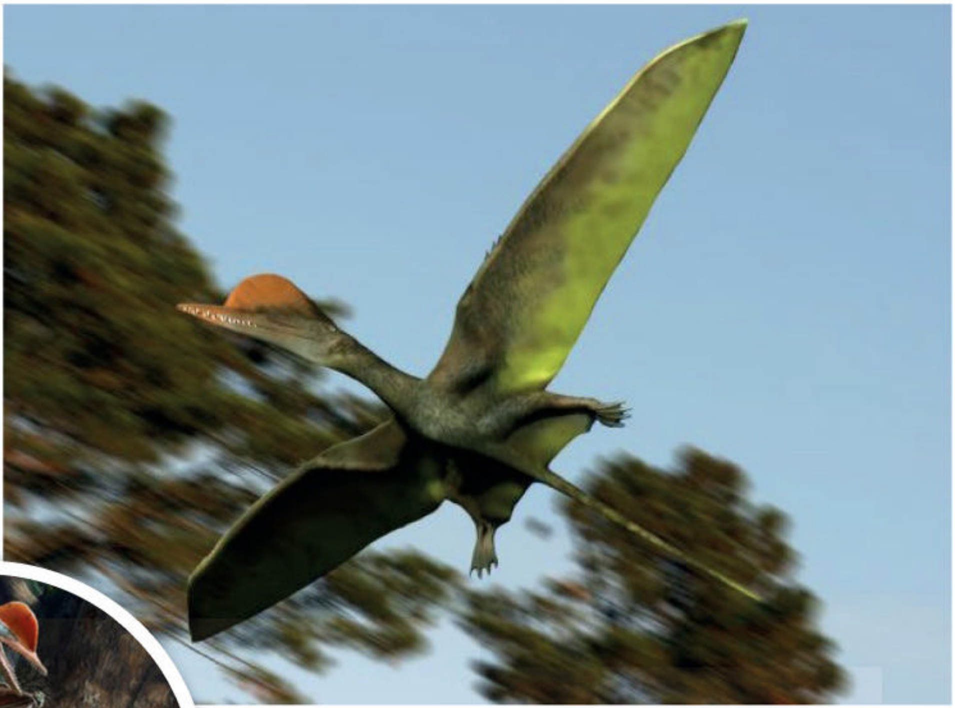
▲ The size of the bumblebee's eyes are important.
Photo courtesy Vasily Menshov/www.shutterstock.com

Foraging early in the day should mean less competition at flowers. This bumblebee, however, is having to divert elsewhere. Photo courtesy Erik Agar/www.shutterstock.com

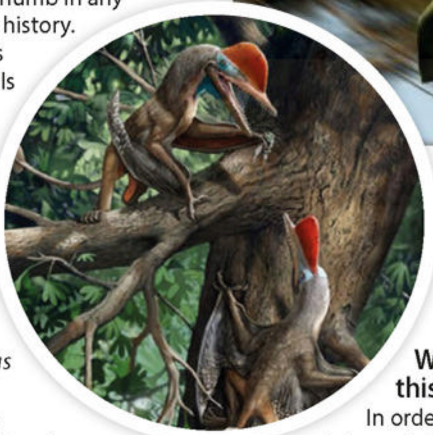
Further reading

Katie Hall, Théo Robert, Kevin J. Gaston, Natalie Hempel de Ibarra. **Onset of morning activity in bumblebee foragers under natural low light conditions.** *Ecology and Evolution*, 2021; DOI: 10.1002/ece3.7506

TREE-DWELLING PTEROSAUR WITH A DISTINCTIVE THUMB



⮝ A living reconstruction of the newly-found pterosaur. Artwork courtesy Chuang Zhao.



⮜ These pterosaurs lived in trees. © Nobu Tamura/CC BY-SA 3.0.

An international team of researchers from China, Brazil, UK, Denmark and Japan have described a new Jurassic pterosaur, dubbed monkeydactyl, and now known officially to science as *Kunpengopterus antipollicatus*. This reptile, which lived about 160 million years ago, was discovered in the Tiaojishan Formation of Liaoning, China.

It is a small-bodied pterosaur, belonging to the Darwinopteran group, with an estimated wingspan of just 85cm (33in). Most importantly, however, this specimen displays an opposed 'thumb' or pollex on both hands, as reflected in its scientific name. In ancient Greek, 'antipollicatus' means 'opposite thumbed', in light of the opposed thumb of the new species. This is the first discovery of a pterosaur with an opposed thumb. Significantly, it also represents the earliest record of a true opposed thumb in any species at all in the Earth's history.

A true opposed pollex is mostly present in mammals such as primates, as well as some tree frogs, but is extremely rare among living reptiles except for chameleons. This discovery adds to the list of reptiles known to possess this feature. The research team scanned the fossil of *K. antipollicatus* using micro-computed tomography (micro-CT), a technique making use of X-ray to image an object. By studying its forelimb morphology and musculature, they suggest that this reptile could have used its hand for grasping, which is likely an adaptation for arboreal life.

Wider implications of this discovery

In order to test the arboreal interpretation, the team analysed this species and other pterosaurs using a set of anatomical characters related to arboreal adaptation. The results support the idea of *K. antipollicatus* as being an arboreal species, but not the other pterosaurs from the same ecosystem. This suggests niche-partitioning among these pterosaurs, meaning they evolved to avoid competing with each other in the same environment, and provides the first quantitative evidence that at least some Darwinopteran pterosaurs were arboreal.

Fion Waisum Ma, based at the University of Birmingham in the UK, explains: "The fingers of monkeydactyl are tiny and partly embedded in the slab. Thanks to micro-CT scanning, we could see through the rocks, create digital models and tell how the opposed thumb articulates with the other finger bones. The results provide the earliest evidence of a true opposed thumb, and it is from a pterosaur - which wasn't a group previously known for having an opposed thumb."

The leader of the study, Xuanyu Zhou from China University of Geosciences, says: "Tiaojishan palaeoforest is home to many organisms, including three genera of Darwinopteran pterosaurs. Our results show that *K. antipollicatus* has occupied a different niche from *Darwinopterus* and *Wukongopterus*, which probably served to minimise competition among these pterosaurs."

In conclusion, Rodrigo V. Pêgas from Federal University of ABC, in Sao Bernardo, Brazil, adds: "Darwinopterans are a group of pterosaurs which lived during the Jurassic Period in China and Europe. They were named after Charles Darwin, thanks to their unique transitional anatomy that has revealed how evolution affected the anatomy of pterosaurs throughout time.

"On top of that, a particular Darwinopteran fossil has been preserved with two associated eggs, revealing clues to pterosaur reproduction. They've always been considered precious fossils for these reasons and it is impressive that new Darwinopteran species continue to surprise us!"

⮝ The opposing thumbs of chameleons ensure they can balance and grip a branch securely. A pygmy leaf chameleon is shown here. They are the only living reptile group displaying this characteristic. Photo courtesy Deatonphotos/ www.shutterstock.com

Further reading

Xuanyu Zhou, Rodrigo V. Pêgas, Waisum Ma, Gang Han, Xingsheng Jin, Maria Eduarda C. Leal, Niels Bonde, Yoshitsugu Kobayashi, Stephan Lautenschlager, Xuefang Wei, Caizhi Shen, Shu'an Ji. **A new darwinopteran pterosaur reveals arborealism and an opposed thumb.** *Current Biology,* 2021 DOI: 10.1016/j.cub.2021.03.030

Living in a world full of killer giant crocodilians

Mega-sized crocodilians might have been kings of the waterways during the Cretaceous period (which extended from 145-66 million years ago). They ate anything—including dinosaurs—that got a little too close to the water's edge, but nevertheless, the largest of these apex predators still started off small.

Figuring out how these little crocs grew up and survived in a world surrounded by giants is no easy task. Now new crocodilian fossils unearthed in the US state of Texas are shedding light on how these reptiles changed their diets as they grew, helping them to survive in environments alongside their bigger, aggressive relatives.

Huge crocodilians were equipped to overpower large prey. Artwork courtesy Michael Rosskothen/www.shutterstock.com

A rare find

The crocodilians in question have been identified as *Deltasuchus motherali* and they lived along the coastline of Texas around 96 million years ago. Previously known from a single adult skull, this 6m (20ft) long species left behind bite marks on turtles and even dinosaurs. The new discoveries include at least 14 more members of *Deltasuchus*, ranging from sizes as large as the original specimen down to a paltry (if not still snappy!) 1.2m (4ft) in length.

Discovering this number of crocs from the same fossil population is not common, and also the smaller, more delicate bones of juveniles often did not survive the fossilisation process. "So many fossil groups are only known from one or a handful of specimens," explains palaeontologist Stephanie Drumheller, who is a lecturer in earth and planetary sciences at the University of Tennessee (UT), Knoxville. "It can be easy to fall into the trap of only thinking about the adults. This find therefore gives us a fairly unique opportunity."

Dinosaurs could fall victim to giant crocodilians in the Cretaceous period - but within the same ecological niche, there could even have been plant-eating crocodilians too. Artwork courtesy Elenarts/www.shutterstock.com

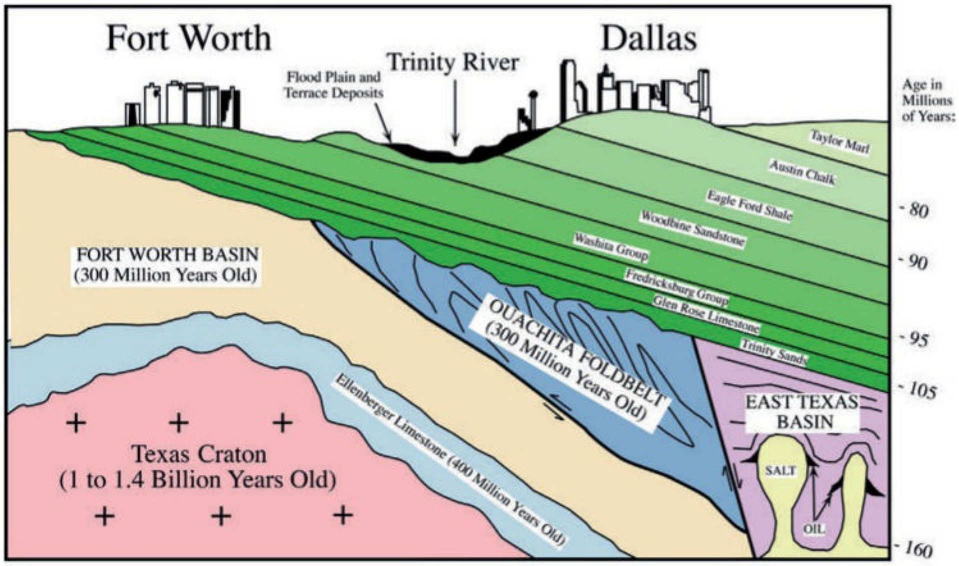
A complex picture of coexistence emerges

The researchers ran into challenges piecing together this ancient ecosystem, however. Deltasuchus wasn't the only species of its type in the coastal swamps where it occurred. Living alongside deltasuchus were other fearsome crocodilians, in the guise of *Terminonaris* and *Woodbinesuchus*.

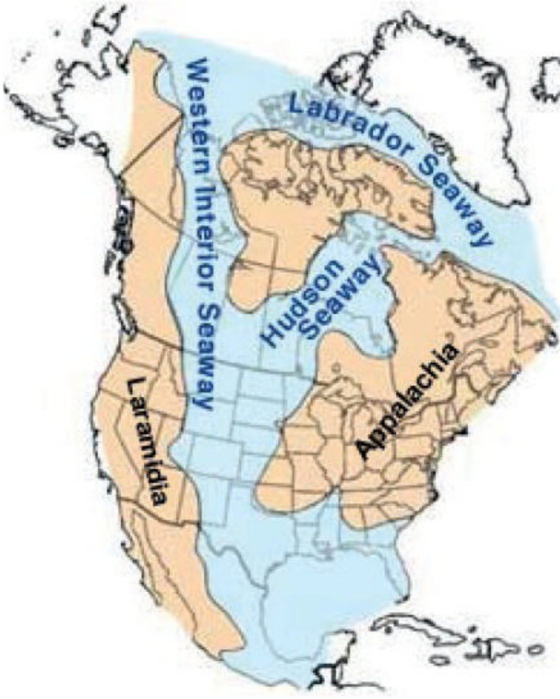
"They were comparable in size to an adult deltasuchus, but because they had long, narrow snouts with slender interlocking teeth, this meant that they were targeting smaller prey in the environment," explains Thomas Adams, curator of palaeontology and geology at the Witte Museum in San Antonio, Texas. In addition, a smaller crocodilian, called *Scolomastax*, lived in this area as well, but its unusual jaw and chunky dentition suggest that it preferred hard food and might even have eaten plants.

"These results confirm previous work that shows fossil crocs were much more diverse and creative when it came to coexisting in the same environments," says Chris Noto, associate professor at the University of Wisconsin–Parkside. "The very warm conditions of the Cretaceous Period, which ultimately ended with the extinction of the dinosaurs and many other life forms some 66 million years ago, supported a greater number of reptiles and allowed them to explore new niches not possible in the present day."

It is possible that maternal protection may have assisted the survival of the young early in life, as in the case of modern species like the American alligator. Photo courtesy Nicolas-SB/www.shutterstock.com


Fort Worth
Dallas
Trinity River
Flood Plain and Terrace Deposits
Age in Millions of Years:
Taylor Marl
Austin Chalk
Eagle Ford Shale
Woodbine Sandstone
Washita Group
Fredricksburg Group
Glen Rose Limestone
Trinity Sands
- 80
- 90
- 95
- 105
- 160
FORT WORTH BASIN (300 Million Years Old)
OUACHITA FOLDBELT (300 Million Years Old)
EAST TEXAS BASIN
SALT
OIL
Texas Craton (1 to 1.4 Billion Years Old)
Ellenberger Limestone (400 Million Years Old)

The so-called Woodbine Formation, between Fort Worth and Dallas in Texas, is the area where the remains of these different crocodilians have been found. Illustration courtesy DFWsection/CC BY-SA 3.0.


Western Interior Seaway
Labrador Seaway
Hudson Seaway
Laramidia
Appalachia

When these ancient crocodilians were alive, what is now North America was split into two by a huge stretch of water, called the Cretaceous Seaway, with these species occurring on the Appalachian side of this divide. Source PD.

Putting the pieces back together

When the group of deltasuchus crocodilians died, their skeletons fell apart as they fossilised, getting jumbled together and subsequently complicating efforts to tell which bones belonged to which individual. In order to assist in solving this puzzle, the team turned to 3D scanning technology, as a means of reconstructing the skulls.

It fell to UT's Hannah Maddox to carry out this task. She meticulously scanned each piece and stitched them together into 3D models of complete skulls. "It was like solving a great puzzle," she explains. "Every piece put in place brought you closer to seeing a toothy grin that hadn't been seen in millions of years!"

A changing lifestyle

As the skulls took shape, a more complete picture of how deltasuchus lived has started to become clear. The juveniles had lighter, skinnier snouts and teeth than their older relatives—faces better suited to snap up quicker, softer prey than the heavier, powerful jaws of their parents.

This might have helped to make sure that small deltasuchus individuals were not in direct competition with the similarly sized hard-prey specialists in their environments, but as they grew, they had other neighbours to consider. The large-bodied, slender-snouted role was already filled by other species. So deltasuchus shifted in another direction as it grew, bulking up and taking on the heavy jaws and sturdy teeth of an ambush predator.

"This is an amazing fossil discovery involving a population of a single species, from an ecosystem that had multiple predators coexisting successfully by filling separate niches," adds fellow researcher Thomas Adams. Interestingly, similar results were recently found in studies of young tyrannosaur dinosaurs, which spent their "teenage" years outcompeting other medium-sized predators within their ecosystems.

Young American alligators today are aided by their banded appearance, which breaks up their outline, helping them to escape detection by would-be predators, including other crocodiles. It is possible that the young of *Deltasuchus* may also have been protected in a similar way. Photo courtesy Wirestock Creators/www.shutterstock.com

Further information

Stephanie K. Drumheller, Thomas L. Adams, Hannah Maddox, Christopher R. Noto. **Expanded Sampling Across Ontogeny in *Deltasuchus motherali* (Neosuchia, Crocodyliformes) Revealing Ecomorphological Niche Partitioning and Appalachian Endemism in Cenomanian Crocodyliforms.** *Elements of Paleontology*, 2021 DOI: 10.1017/9781009042024

The mystery of the 'lost years' is solved?

It has been a long-standing puzzle as to where young turtles disappear during their so-called 'lost years'. Now, however, a new study involving green turtles (*Chelonia mydas*) has shed light on this question, and it is hoped that the results will inform conservation efforts to protect these threatened reptiles.

The new research indicates that the legendary Sargasso Sea, which includes part of the Bermuda Triangle and has long featured in fiction as a place where ships disappear, may actually provide an important nursery habitat for young sea turtles. The new findings echo the team's previous research that showed baby loggerhead turtles (*Caretta caretta*) arrive at the Sargasso Sea.

⮝ A young green turtle heading to the sea. Photo courtesy JHVEPhoto/www.shutterstock.com

⮜ A young green turtle swims off from its nesting beach, but very little has been recorded about their early life at sea. Photo courtesy apple-of-the-earths/www.shutterstock.com

Tracking provides unexpected results

This study represents the first time that green sea turtles have been tracked during their early 'lost years'. This is defined as the time period between hatching from their nests along Florida's Atlantic coast and heading immediately into the ocean, before their subsequent return to coastal habitats after several years out at sea. Not much has been known about where the turtles go during this period, explaining where the 'lost years' description originates.

The Atlantic coastline of Florida is a major nesting area for both green and loggerhead sea turtles, which are iconic species in conservation terms and also important in helping to maintain ocean ecosystems, according to UCF Biology Associate Professor Kate Mansfield, who led the study in collaboration with Jeanette Wyneken at Florida Atlantic University.

What was anticipated

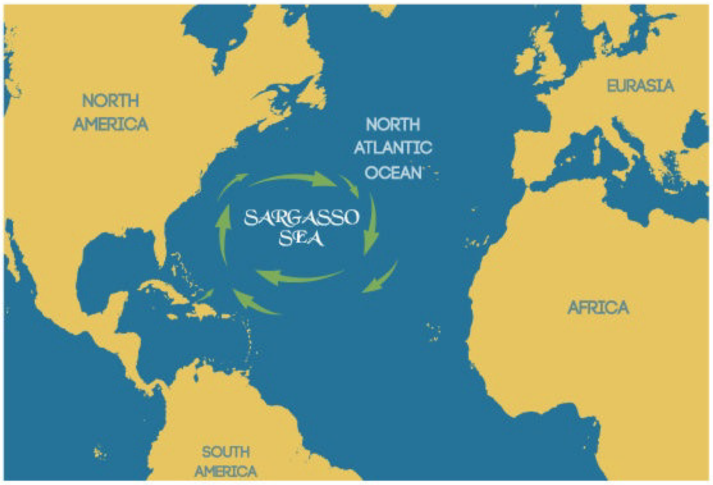
Scientists had long assumed that having entered the ocean from their hatching beaches, baby sea turtles would passively drift in sea currents, such as those circulating around the Atlantic Ocean, and ride those currents until their later juvenile years.

"The idea that some turtles might leave the currents and actively head into the Sargasso Sea was not ever considered or predicted by long-held hypotheses and the assumptions in the field," Mansfield admits. "We found that the green turtles actively oriented to go into the Sargasso Sea and in even greater numbers than the loggerheads we tracked in our earlier work. Granted, our sample sizes aren't huge, but enough turtles made this journey so that it really throws into question our long-held beliefs about the early lives of sea turtles."

The Sargasso Sea, located off the east coast of the US in the North Atlantic, has often been featured in popular culture, such as in Jules Verne's book entitled *Twenty Thousand Leagues under the Sea*, being a place where ships could become trapped when trying to travel through the thick mats of the floating brown sargassum seaweed, after which this region of the ocean is named.

Technology proves invaluable

The researchers were able to track the turtles by attaching advanced solar-powered tracking devices, measuring about 2.5cm (1in) in length, to their shells. This also required determining the optimum adhesive for applying the sensor, which was different for the green turtles compared with loggerheads



⮝ The location and currents of the Sargasso Sea. Artwork courtesy WindVector/www.shutterstock.com

⮝ The team had previously investigated the movements of young loggerhead turtles after hatching. Photo courtesy Tommy Daynjer/www.shutterstock.com

An oceanic stage green sea turtle released with a solar-powered satellite tag in sargassum habitat. Photo courtesy Gustavo Stahelin, UCF MTRG. Permit number NMFS-19508.

because of the greens' seemingly waxier type of shell. The tracking device is designed to fall off after a few months and does not hurt the turtles or inhibit the turtles' shell growth or behaviour.

In this study, 21 green sea turtles which were all less than a year old had transmitters affixed and were released into the Gulf Stream ocean currents about 16km (10ml) offshore from the beach where they hatched. The researchers were able to track the turtles for as long as 152 days using this system.

Of this group, 14 departed the Gulf Stream and the North Atlantic gyre of circulating currents, and entered the western or northern Sargasso Sea region in the western Atlantic Ocean, according to the results in this case. This is compared with seven out of 17 loggerhead turtles that left the Gulf Stream and entered the Sargasso Sea in the previous study.

Wyneken, a professor of biological sciences and director of Florida Atlantic University's Marine Science Laboratory at Gumbo Limbo Environmental Complex, worked with Mansfield to collect, raise, tag and release the turtles.

She says the research is important because it sheds light on where the baby turtles go during a delicate period in their lives.

"These studies in which we learn where young sea turtles go to start growing up are fundamental to sound sea turtle conservation," Wyneken explains. "If we don't know where they are and what parts of the ocean are important to them, we are trying to conserve them blindfolded."

Interpreting the data

Dr Jiangang Luo, a scientist with the Tarpon Bonefish Research Center at the University of Miami's Rosenstiel School of Marine and Atmospheric Science, has a background in mathematical biology, oceanography and advanced scientific data visualisation. As part of the research team, he helped process and analyse the data, also graphing and animating the results.

The Sargasso Sea Commission, which works as a steward for the area with support from multiple governments and collaborating partners, will use data from this research as part of its upcoming ecosystem project. This will quantify threats and their potential impact on the Sargasso Sea, including climate change, pollution by plastics and commercial activities, as well as investigating ways to counter challenges that the region faces and establish a baseline for ongoing monitoring and adaptive management.

Further studies planned

"Dr. Mansfield's research into the critical habitat that this area provides for turtles early in their life cycle gives concrete evidence of the importance of the Sargasso Sea for endangered and critically endangered species. It is one of the many reasons why conservation of this high-seas ecosystem is vitally important for marine biodiversity," says Teresa Mackey, the Commission's Programme Manager.

The next planned steps for the "lost years" research will include looking more closely at differences in orientation and swimming behaviour between turtle species, understanding the role that sargassum plays in early sea turtle development, and testing newer, smaller, and more accurate tracking devices to learn more about the places that the baby turtles go and how they interact with their environment.

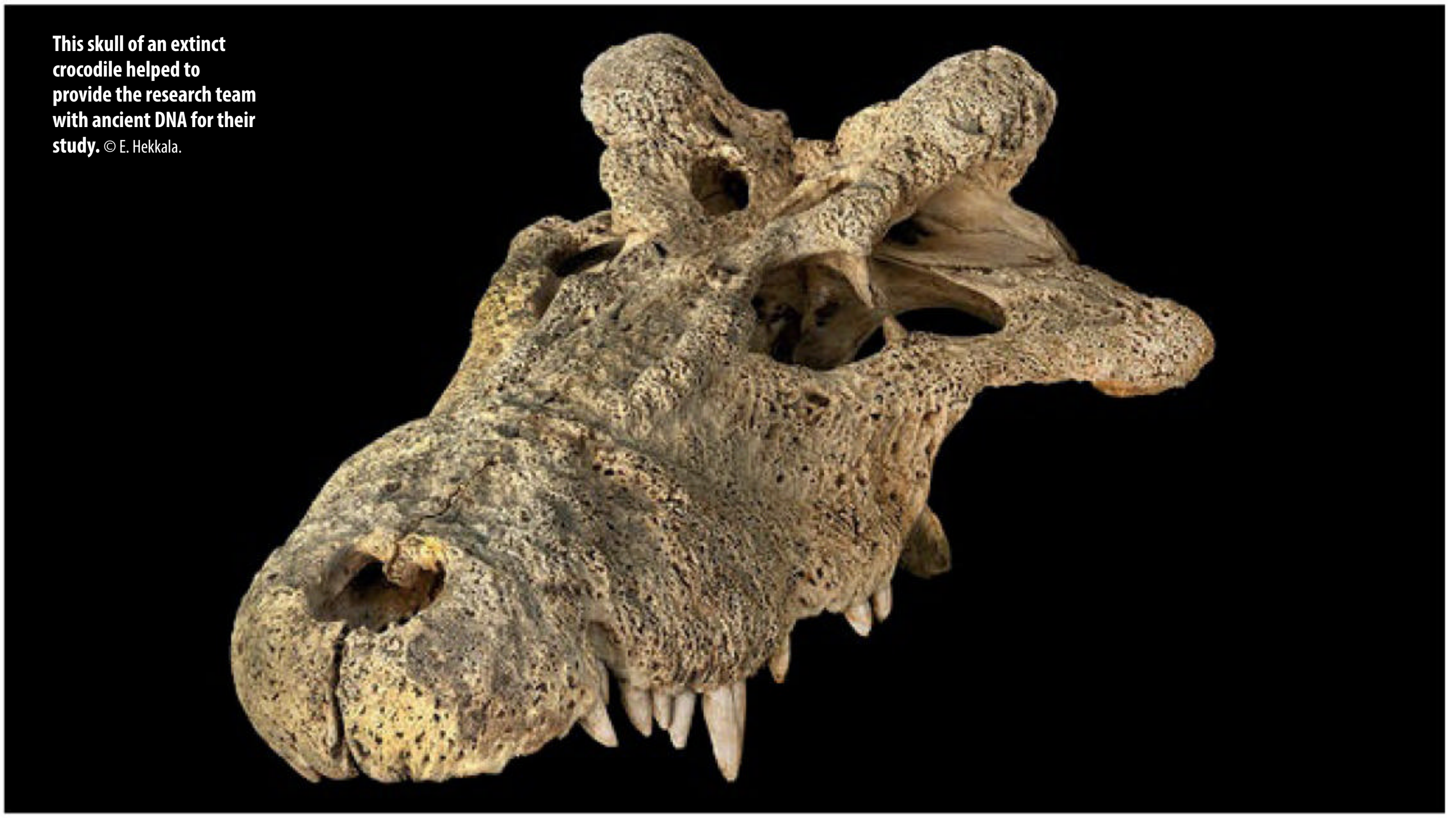
▲ **Sargassum seaweed in close-up. It provides both food and shelter for many sea creatures in the Atlantic Ocean.** Photo courtesy Allen McDavid Stoddard/www.shutterstock.com

Further information

Katherine L. Mansfield, Jeanette Wyneken, Jiangang Luo. **First Atlantic satellite tracks of 'lost years' green turtles support the importance of the Sargasso Sea as a sea turtle nursery.** *Proceedings of the Royal Society B: Biological Sciences*, 2021; 288 (1950) DOI: 10.1098/rspb.2021.0057

▲ **Changes in currents are seeing the sargasso seaweed washed up on beaches, potentially threatening the unique ecosystem associated with this habitat.** Photo courtesy in2dodo/www.shutterstock.com

The horned crocodilian of Madagascar



This skull of an extinct crocodile helped to provide the research team with ancient DNA for their study. © E. Hekkala.

New research based on two skulls that have been in the American Museum of Natural History's collection since the early 1930s resolves a long-standing controversy about an extinct "horned" crocodilian that lived on Madagascar until a few centuries ago. It has given new insight into where today's crocodiles as a group first appeared. The research team also discovered that the horned crocodile (*Voay robustus*), so-called because of the two bony knobs on the top of its head, was closely related to true crocodiles, but occupied a separate branch of the crocodile family tree.

A recent loss

"This crocodilian was hiding out on the island of Madagascar during the time when people were building the pyramids and was probably still there when pirates were getting stranded on the island," explains Evon Hekkala, an associate professor at Fordham University and a research associate at the Museum. "The species disappeared just before we had the modern genomic tools available to make sense of the relationships of living things. And yet they are the key to understanding the story of all the crocodiles alive today."

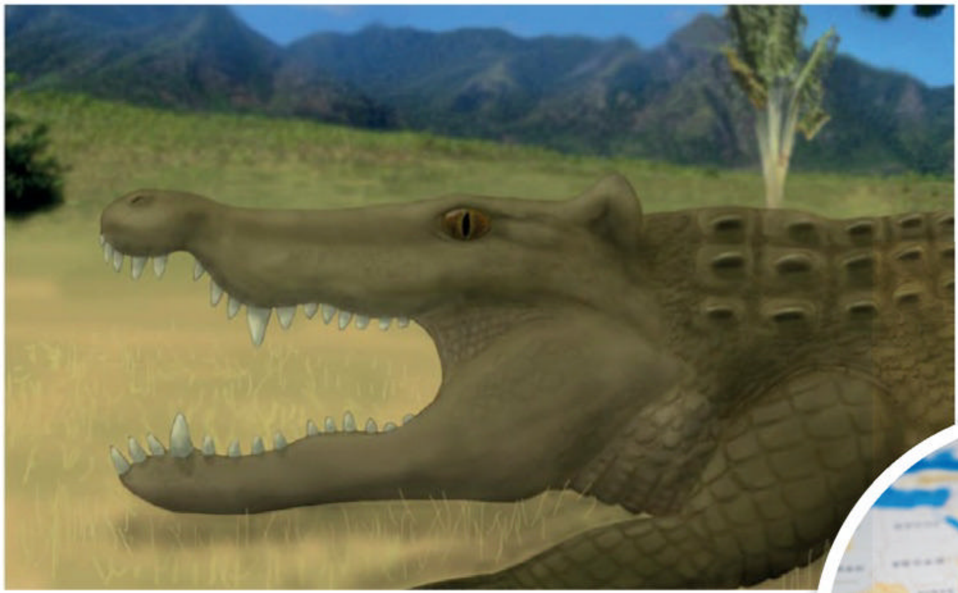
Early explorers to Madagascar noted that Malagasy peoples consistently referred to two types of crocodile on the island: a large, robust species and a more slender form with a preference for rivers, suggesting that both types existed until very recently. But only the latter type, now recognised as an isolated population of the Nile crocodile (*Crocodylus niloticus*), is currently found on the island.

⮝ **The island of Madagascar was home to this unique species of horned crocodilian.** Photo courtesy Shinelu/www.shutterstock.com

A long-standing puzzle

Despite nearly 150 years of investigation, the position of the horned crocodile in the tree of life has remained controversial. During the 1870s, it was first described as a new species within the 'true crocodile' group, which includes the Nile, Asian, and American crocodiles. In the early part of the 20th century, however, it was thought that the specimens simply represented very old Nile crocodiles.

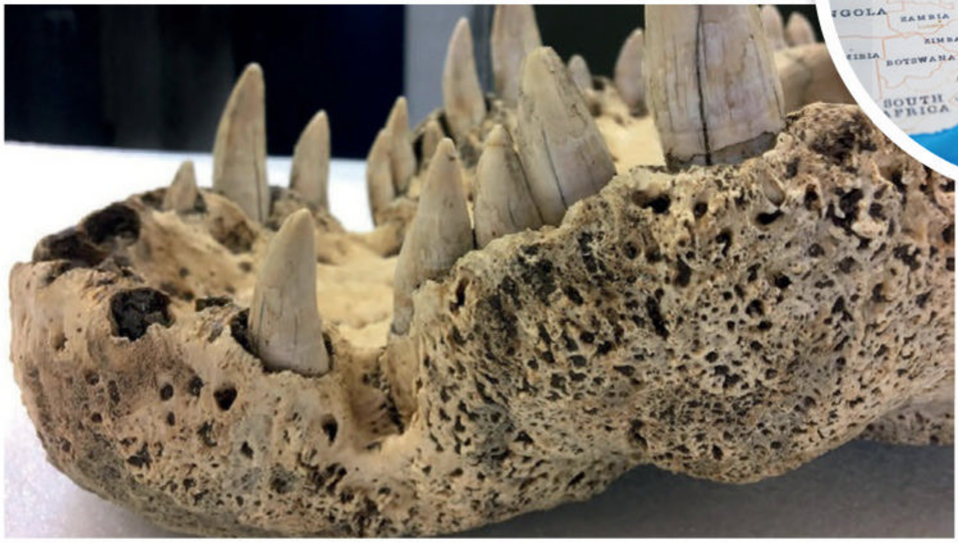
Then, in 2007, a study based on physical characteristics of the fossil specimens concluded that the horned crocodile was not



A reconstruction of the horned crocodile's distinctive head. Artwork courtesy smokeybjb/CC BY-SA 3.0

Madagascar used to be home to different types of crocodile. Artwork courtesy hyotographics/www.shutterstock.com

CONGO
TANZANIA
ZAMBIA
MOZAMBIQUE
ZIMBABWE
MADAGASCAR
BOTSWANA
SOUTH AFRICA



This skull of the extinct horned crocodile from Madagascar *(Voay robustus)* has been part of the American Museum of Natural History's scientific collections since the early 1930s. Photo courtesy M. Ellison/© AMNH.

actually a true crocodile, but should be included in the group that includes dwarf crocodiles. "Teasing apart the relationships of modern crocodiles is really difficult because of the physical similarities," Hekkala explains. "Many people don't even realise that there are multiple species, and they see crocodiles as this animal that's unchanging through time. But we've been trying to get to the bottom of the great diversity that exists among them."

New insight

In order to investigate the horned crocodile's place in the evolutionary tree, Hekkala and her collaborators at the Museum made a number of attempts to sequence DNA from fossil specimens, including two well-preserved skulls that were collected during the Museum's Mission Franco-Anglo-American expedition from 1927–1930.

"This is a project we've tried to do on and off for many years, but the technology just hadn't advanced enough, so it always failed," admits study co-author George Amato, emeritus director of the Museum's Institute for Comparative Genomics. "But this time, we had both the palaeo-genomic techniques and the computational setup that meant we could actually obtain the DNA from the fossil remains and finally sort out its place in the crocodile family tree."

Where crocodiles originated

The results place the horned crocodile right next to the true crocodile branch of the evolutionary tree. It is therefore the closest known species to the common ancestor of the crocodiles that are alive today.

"This finding was surprising and also very informative as to how we think about the origin of the true crocodiles found around the tropics today," Amato says. "The placement of this individual suggests that true crocodiles originated in Africa and from there, some went to Asia and others ended up in the Caribbean and the New World. We really needed the DNA to get the correct answer to this long-standing, critical question."

Further information

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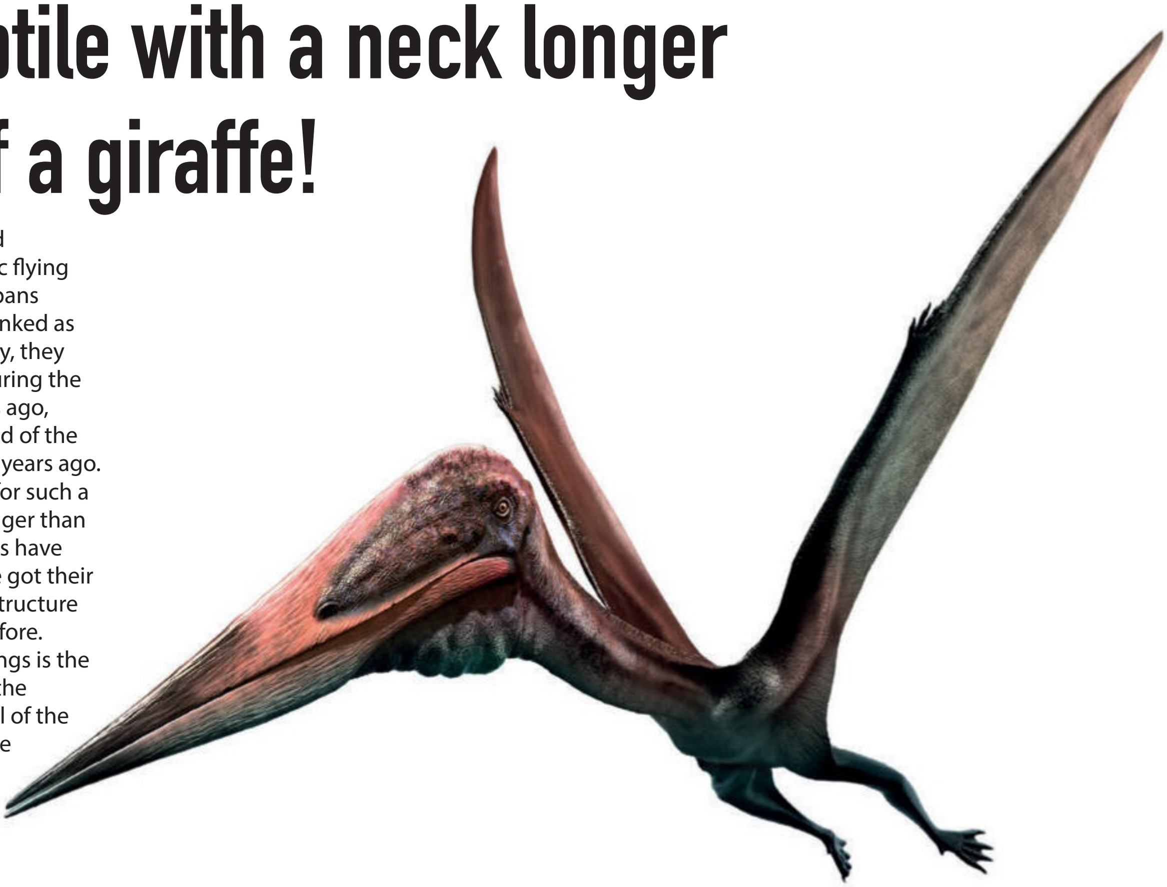
Only very recently has the technology progressed far enough to allow the fossil DNA of this crocodilian to be extracted and studied. Photo courtesy Chansom Pantip/www.shutterstock.com

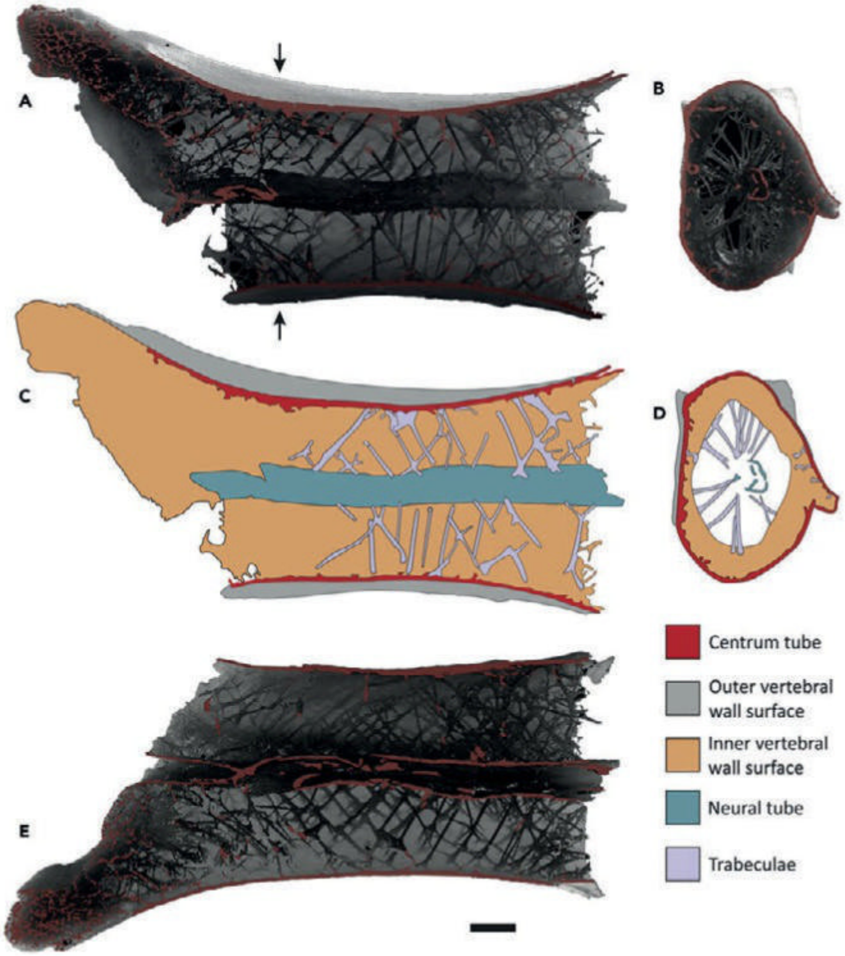
A flying reptile with a neck longer than that of a giraffe!

Little is known about azhdarchid pterosaurs, which were gigantic flying reptiles with impressive wingspans measuring up to 12m (39ft). Ranked as the largest animals ever known to fly, they first appeared in the fossil record during the Late Triassic about 225 million years ago, before disappearing again at the end of the Cretaceous period about 66 million years ago. One of their most notable features for such a large flighted animal was a neck longer than that of a giraffe. Now, UK researchers have found that their thin neck vertebrae got their strength from an intricate internal structure unlike anything that's been seen before.

"One of our most important findings is the arrangement of cross-struts within the vertebral centrum," says Dave Martill of the University of Portsmouth. "It is unlike anything seen previously in a vertebra of any animal. The neural tube is placed centrally within the vertebra and is connected to the external wall via a number of thin rod-like trabeculae, radially arranged like the spokes of a bicycle wheel and helically arranged along the length of the vertebra. They even cross over like the spokes of a bicycle wheel. Evolution shaped these creatures into awesome, breathtakingly efficient flyers."



Azhdarchid pterosaurs such as zhejiangopterus rank amongst the largest flying species ever seen on the Earth. They were also characterised by having very long necks.

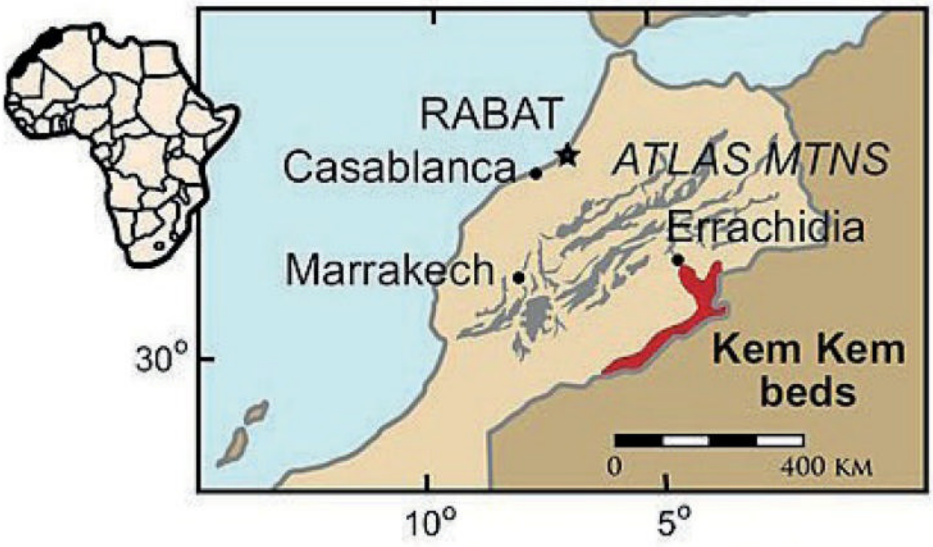


The totally unique structure of the pterosaur's neck.
Image courtesy Cariad J. Williams, David M. Nartill et al..

Unexpected findings

Scientists previously thought the pterosaur's neck had a simpler tube-within-a-tube structure, he explains. But it raised an important question: how could their thin-walled bones, needed to reduce weight in the flying reptiles, still support their bodies and allow them to capture and eat heavy prey animals? Cariad Williams who started this research, hadn't set out to answer that question! She simply wanted to examine the degree of movement between each vertebra of the pterosaur's neck.

"These animals have ridiculously long necks," Williams says, adding that, in some species, the fifth vertebra of the neck from the head end is as long as the animal's body. "It makes a giraffe look perfectly normal. We wanted to know a bit about how this incredibly long neck functioned, as there seems to have been very little mobility between each vertebra."



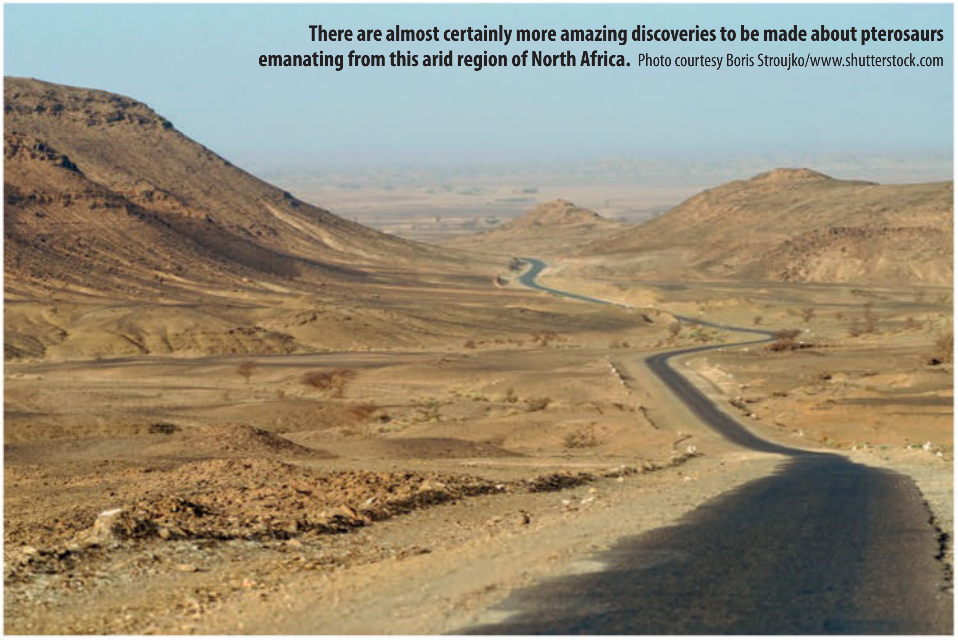
The Kem Kem fossil beds lie on the southern border of the North African country of Morocco. Artwork courtesy Nizar Ibrahim, Paul C. Sereno, David J. Varricchio, David M. Martill, Didier B. Dutheil, David M. Unwin, Lahssen Baidder, Hans C. E. Larsson, Samir Zouhri, Abdelhadi Kaoukaya

Remarkable preservation

While the Moroccan pterosaur bones that the scientists studied are well preserved in three dimensions, they still hadn't expected the scans to offer such a clear view of the intricate internal structure of the vertebra. "We did not originally CT-scan it to learn about the inside; we wanted a very detailed image of the outside surface," Martill explains. "We could have got this by ordinary surface scanning, but we had an opportunity to put some specimens in a CT scanner, and it seemed churlish to turn the offer down. We were simply trying to model the degree of movement between all the vertebrae to see how the neck might perform in life."

He adds: "What was utterly remarkable was that the internal structure was perfectly preserved, and so too was the microhistology, when we looked at some sections of the fossilised bone. As soon as we saw the intricate pattern of radial trabeculae, we realised there was something special going on. As we looked closer, we could see that they were arranged in a helix travelling up and down the vertebral tube and crossing each other like bicycle wheel spokes."

The Kem Kem basin deposits in Morocco have revealed some truly remarkable finds about pterosaurs. This tooth is from *Siroccopteryx moroccoensis*, another giant pterosaur with a 6m (20ft) wingspan and is 96 million years old.



There are almost certainly more amazing discoveries to be made about pterosaurs emanating from this arid region of North Africa. Photo courtesy Boris Stroujko/www.shutterstock.com

Engineering advice sought

His team realised immediately that they needed to bring in engineers to understand how the biomechanics of this unusual neck would have worked. Those analyses suggest that as few as 50 of the spoke-like trabeculae increased the amount of weight the necks of these azhdarchid pterosaurs could carry without buckling by 90%. Together with the basic tube-within-a-tube structure, it explains how these relatively lightweight animals could capture and carry heavy prey items without breaking their necks.

"It appears that this structure of extremely thin cervical vertebrae and added helically arranged cross-struts resolved many concerns about the biomechanics of how these creatures were able to support massive heads — longer than 1.5m (5ft) — on necks longer than the modern-day giraffe, all whilst retaining the ability of powered flight," Martill explains.

While pterosaurs as a group are sometimes thought of representing an evolutionary dead end, Martill and colleagues say the new findings reveal them once again as having been "fantastically complex and sophisticated" creatures. Their bones and skeletons were marvels of biology—extremely light yet strong and durable. They point out that there's also still much to learn about pterosaurs, including even seemingly basic questions about their flying abilities and feeding ecology.

Further information

Williams et al. **Helically arranged cross struts in azhdarchid pterosaur cervical vertebrae and their biomechanical implications.** *iScience*, 2021 DOI: 10.1016/j.isci.2021.102338

The relationship between snake diets and venom

The cottonmouth or water moccasin (*Agkistrodon piscivorus*) is the only venomous water snake in North America, and the world's only semi-aquatic viper, typically frequenting areas of marshland, occurring close to water. It feeds on a wide variety of prey, including fish, amphibians and mammals.
Photo courtesy Mark_Kostich/www.shutterstock.com

Diversity in diet plays a role in the complexity of venom in pit vipers such as rattlesnakes, copperheads and cottonmouths. But new collaborative research by Clemson University scientists, based in the US state of South Carolina, found the number of prey species that a snake ate did not determine the complexity of the venom. Rather, it was how far apart the prey species were from each other in evolutionary terms that mattered in this regard.

The key driver

"It's not just diet that drives the variation in venom across snakes. It's the breadth of diet," says Christopher Parkinson, a professor in the College of Science's Department of Biological Sciences. "If a snake eats 20 different species of mammal, its venom will not be very complex. But if it eats a centipede, a frog, a bird and a mammal, it's going to have a highly complex venom, because each component of its venom is going to affect something different in each of these prey species."

Lasting injury

"Snakebite is a neglected tropical issue. It doesn't kill many people in the US—only around eight per year—but it can cause lasting injury such as neurological and tissue damage. Even though we have good anti-venoms, they could certainly be better," says Matthew Holding, who led the research.

"We have produced a library of the venoms of all the species in the US in a higher level of detail than has been done before, so somebody else who is interested in improving anti-venoms could use this information." The team included scientists not just from Clemson University, but also from Florida State University, Mexico and Brazil, allowing them to study the venoms and diets of 46 species of North American pit viper, including all those found in the USA.

⮝ Former Clemson University researcher Matthew Holding. Photo courtesy Matthew Holding.

Rather like a toolbox

Information about the diets of those species was then used to understand why some venoms are simple and others are very complex. Venoms contain proteins that collectively function to incapacitate prey. The number of different proteins that the venom contains reflects its complexity.

"You can think of venom as a snake's toolbox. A wrench, a socket and a screwdriver

A Western pygmy rattlesnake (*Sistrurus miliarius streckeri*) consumes a frog that it has caught. Photo courtesy Kyle Hutchison.

each have a different use. Likewise, each protein has a different function when the venom is injected into a mouse, lizard, centipede or whatever prey the snake is eating," Holding explains.

"Some snakes have much simpler venoms with fewer components. Some have many more. We wanted to understand, from an evolutionary standpoint, why that might be," says Holding, who is now based at Florida State University.

Venom comparisons

Researchers collected venom and venom gland samples from rattlesnakes and cottonmouths across North America. They applied next-generation sequencing techniques to create the largest dataset of venoms of viperid snakes that has yet been produced. Using natural history specimens, researchers compared venom complexity to the diets of the different species featured in the study.

"Having a prey database based on natural history specimens was paramount because we could not have done this work without those museum collections. We could not have built a comparative framework to compare snakes' diet and evolutionary history without them," adds Christopher Parkinson.

Photo courtesy Joe McDonald/www.shutterstock.com

A detailed understanding of the constituents of the venom of viperid snakes was gained through this research.

A black-tailed rattlesnake (*Crotalus molossus*) poised to strike. When hunting, its venom needs to be able to overcome its particular prey effectively. Photo courtesy Joe McDonald/www.shutterstock.com

Christopher Parkinson. Photo courtesy Christopher Parkinson.

Further reading

Matthew L. Holding, Jason L. Strickland, Rhett M. Rautsaw, Erich P. Hofmann, Andrew J. Mason, Michael P. Hogan, Gunnar S. Nystrom, Schyler A. Ellsworth, Timothy J. Colston, Miguel Borja, Gamaliel Castañeda-Gaytán, Christoph I. Grünwald, Jason M. Jones, Luciana A. Freitas-de-Sousa, Vincent Louis Viala, Mark J. Margres, Erika Hingst-Zaher, Inácio L. M. Junqueira-de-Azevedo, Ana M. Moura-da-Silva, Felipe G. Grazziotin, H. Lisle Gibbs, Darin R. Rokyta, Christopher L. Parkinson. **Phylogenetically diverse diets favor more complex venoms in North American pit vipers.** *Proceedings of the National Academy of Sciences,* 2021; 118 (17): e2015579118 DOI: 10.1073/pnas.2015579118

NEW DISCOVERIES ABOUT DART FROG BREEDING BEHAVIOUR

Studies involving dyeing dart frogs gave some very unexpected results. Photo courtesy reptiles4all/www.shutterstock.com

Relatively little is known about the breeding habits of many species of amphibian in the wild. An international expedition, comprised of researchers from the University of Jyväskylä in Finland and Stanford University in the US has just returned from French Guiana, where they investigated tropical frogs in the Amazon region, and made some remarkable discoveries.

Breeding behaviours

Various amphibian species found in this region use temporary (or 'ephemeral') pools as their nurseries, and they generally show individual preferences for water which has particular physical and chemical characteristics. As a result, researchers were surprised to find tadpoles of the dyeing poison frog (*Dendrobates tinctorius*) thriving in water with widely varying pH readings, and also present in different deposition sites, extending from ground level up to more than 20m (66ft) off the ground.

Chloe Fouilloux, team leaders Dr. Bibiana Rojas from University of Jyväskylä, Finland and Dr. Andrius Pašukonis from Stanford University set out to discover if different species sought a combination of biological, physical and/or chemical characteristics of pools when choosing nurseries for their young. Their research focused on three species: the dyeing poison dart frog, plus the spotted-thighed poison dart frog (*Allobates femoralis*) and *Osteocephalus oophagus*.

Plenty of tree-climbing involved

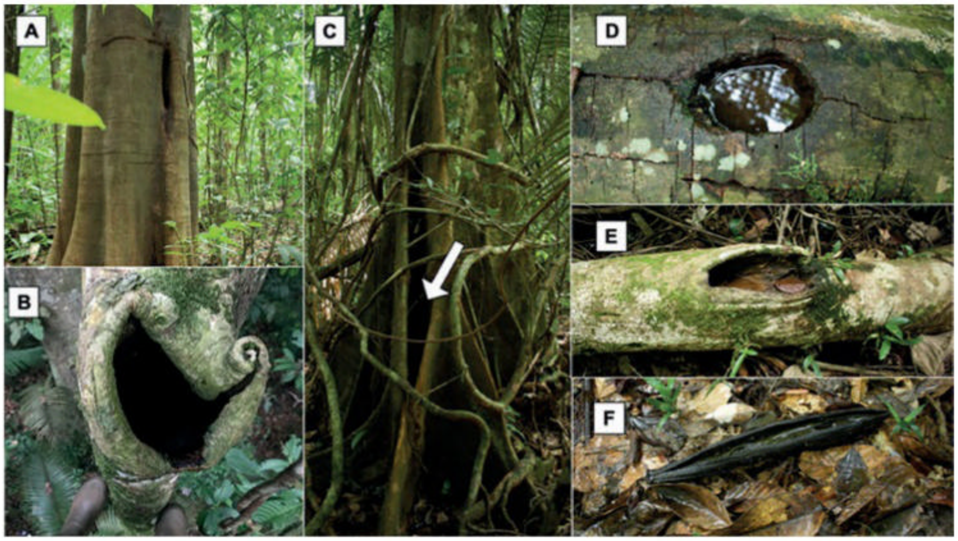
In order to obtain answers, the research team sampled more than 100 pools over the course of the study. This involved searching for suitable tadpole deposition sites located from ground level up to heights which entailed plenty of tree-climbing.

Out of the three species, the range and tolerance of the dyeing poison dart frog tadpoles were quite beyond what any of the researchers had imagined physiologically possible. They discovered healthy tadpoles in a wide range of pools, where the pH reading varied from 3-8, which represents a 100,000x change of hydrogen ion concentration. To put these findings into context, these tadpoles

BERMUDA
BAHAMAS
HAITI
DOMINICAN REPUBLIC
PUERTO RICO
ST. KITTS
ANTIGUA
BARBUDA
MONTSERRAT
GUADELOUPE
DOMINICA
MARTINIQUE
ST. LUCIA
BARBADOS
ST. VINCENT
GRENADA
TRINIDAD
ARUBA
CURACAO
Caracas
VENEZUELA
GUYANA
Georgetown
SURINAME
FRENCH GUIANA
Amazon River
Belem
Porto Velho

The expedition spent two years carrying out research in French Guiana. Map courtesy hyotographics/www.shutterstock.com

The less colourful spotted-thighed poison dart frog also featured in this research. It is a terrestrial species. Photo courtesy Patrick K. Campbell/www.shutterstock.com



Photographs show the diversity of pools across the vertical gradient. Water-filled cavities in plants (described as 'phytotelmata') used by frogs include "live" substrate pools such as tree holes (a), high arboreal pools (b), and buttresses (c). There were also commonly occupied "dead" substrate pools such as fallen trees (d, e) and palm bracts (f). Photo courtesy Andrius Pašukonis/Stanford University.

were developing normally in pools where the water is chemically more acidic than orange juice through to others that have similar ionic concentrations to sea water!

The deposition choices of dyeing poison frogs confused researchers in other ways, too: tadpoles in this case are aggressively cannibalistic, which is why they are usually found to occur in low densities (typically only 1-2 tadpoles) per pool."However, in this study, we found several instances of more than 10 tadpoles of this species co-existing in the same nursery. The reason why fathers would deposit so many cannibalistic tadpoles within the same pool, or if cannibalism occurs within these special pools, has yet to be tested," says Chloe Fouilloux.

Why the long haul?

There is also the question as to whether healthier male frogs of this species transport their tadpoles to more suitable locations, enhancing their chances of survival? From a parental perspective, dyeing poison dart frog fathers were found to carry their tadpoles up to heights of more than 20m (66ft) above the forest floor on their backs: for a frog that is about 4cm (1.6in) long, that distance represents 500 times their body length. In human terms, this physical feat would be equivalent to having a 1.65m (5.5ft) person climbing up a giant (non-existent, obviously) tree of about 825m (2707ft) in height!

But why do some males carry their tadpoles just a metre (3ft) away from where they hatched in certain cases, while transporting them to the tops of trees on other occasions? When looking at the chemical and biological trends, it appears this is because more biologically suitable nurseries are found higher up in trees.

It is unclear if fitter males are more likely to climb. Photo courtesy Andrius Pašukonis/Stanford University.

Much more to discover

It could be that the stronger males are able to invest greater energy in transporting their tadpoles to more suitable conditions, but this is something that would need to be investigated in the future. Ultimately, there remains a lot to be learnt about the physiology and parental care of these amphibians; the water chemistry adaptability found in these tadpoles is extremely unusual, and the secret underlying their resilience remains unknown.

"This work assists in highlighting the amazing diversity observed between and among species in the wild: parents from different species prioritise unique characteristics when choosing pools to raise their offspring, which shapes both how species interact with each other and how they specialise in occupying different parts of their environments," adds Dr. Bibiana Rojas.

These differences open the door to future research that will explore how species influence each other, and how pool choice by parents affects the development and survival of their tadpoles. It may also be worth thinking again about how to set up an enclosure for these poison dart frogs when spawning them in vivarium surroundings, providing suitable localities off the ground.

Further information

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Why wall lizards have thrived

⮝ **Wall lizards are the most widely-distributed group of reptiles in the Mediterranean region.** Photo courtesy Anton Balazh & NASA/www.shutterstock.com

A new study may have uncovered why wall lizards have become the most successful group of reptiles in the Mediterranean region. The researchers believe they can now explain why the lizards became so diverse and widespread, which is a mystery that has puzzled biologists since the 19th century.

The origins of wall lizards as a group date back around 20 million years. However, the number of species seems to have increased significantly soon after the Messinian Salinity Crisis which occurred six million years ago. During this period, the Mediterranean almost dried out, only to fill up with water again rapidly from what is now the Atlantic ocean, as the Strait of Gibraltar opened.

Mequinenza
Tarragona
Ebro
SPAIN
BALEARIC ISLANDS
(SPAIN)
Castellón de la Plana
Ciudadela
Minorca
Mahon
Inca
Manacor
Palma
Llucmajor
Majorca
Turia
Valencia
Júcar
Cabrera
Ibiza
Ibiza
Formentera
BALEARIC SEA

⮝ **Diversity is very apparent amongst wall lizard populations on many islands in the Mediterranean, including the Balerics.** Map courtesy Peter Hermes Furian/www.shutterstock.com

⮝ **Tobias Uller, professor of evolutionary ecology, who led this study.** Photo courtesy Tobias Uller.

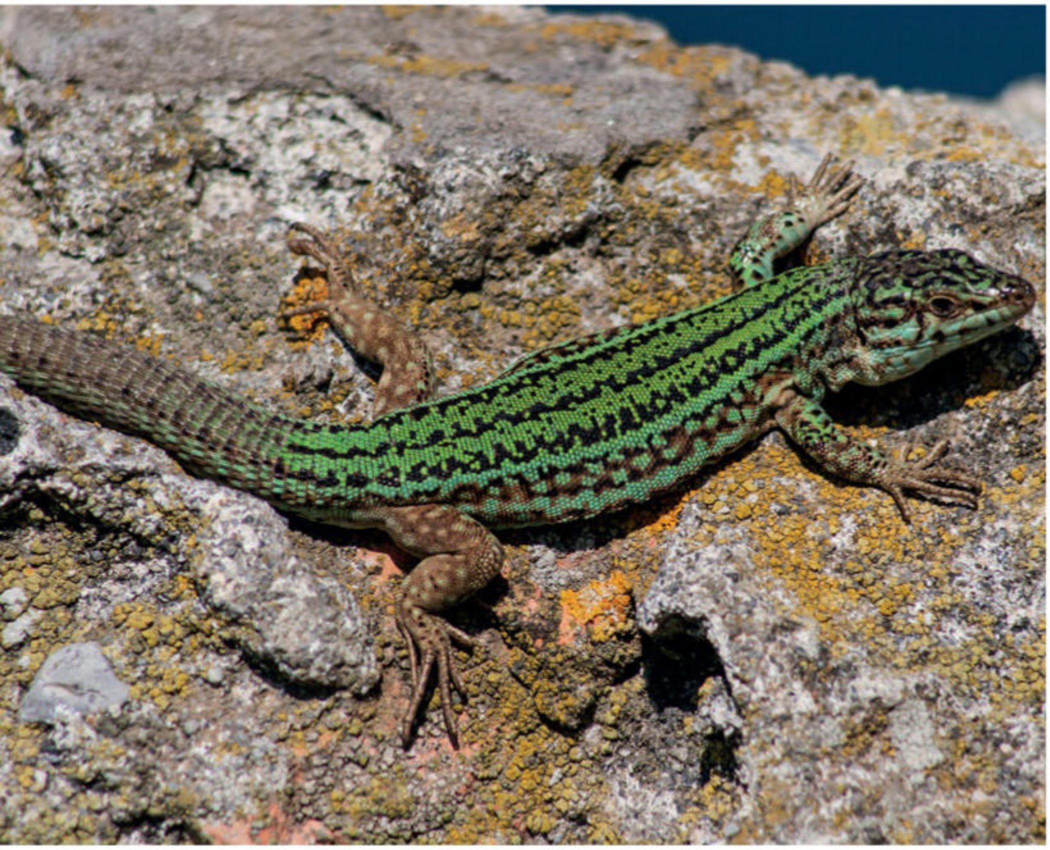
Chance encounters

"Our results show that the dramatic changes at that time probably contributed to the emergence of new species of wall lizard. They also shed light on why biodiversity there looks the way it does today," says Tobias Uller, professor of evolutionary ecology at Lund University in Sweden, who led the international study. The research indicates that species isolated from each other for millions of years occasionally have found each other and shared genes.

By comparing DNA sequences from 26 species and 8 subspecies, the team successfully mapped the major features of the

⮝ True to their name, these lizards may hide away in rocky crevices, including walls. This individual was photographed on the Peloponnese peninsula in Greece. Photo courtesy siete_vidas/www.shutterstock.com

The wall lizard population from the adjacent island of Formentera has a very different appearance, both in terms of its patterning and colouration, compared with those found on Ibiza.
Photo courtesy AnaOcc/www.shutterstock.com



⮝ An Ibiza wall lizard (*Podarcis pityusensis*). Photo courtesy Manuel Ocen/www.shutterstock.com

evolution of wall lizards. This included what parts of the genome were transferred from other species through hybridisation.

A case of this type

One example is the wall lizards found on Ibiza. Half of their genes come from wall lizards that today live on the Iberian Peninsula, and the other half from those found in the Balkans and among the Greek islands. The species in Ibiza thus originated as a hybrid, which provided evolution with great opportunities to combine old genes in new ways.

According to the researchers, this probably explains why species like the Ibiza wall lizard are so strikingly variable in colouration: despite close relationships and geographic proximity, they are a single colour on one island, but a variety of colours on the next, for example. "We believe that hybridisation has fuelled evolution in this case, promoting biodiversity and extraordinary adaptability among certain species," concludes Tobias Uller.

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Weizhao Yang, Nathalie Feiner, Catarina Pinho, Geoffrey M. While, Antigoni Kaliontzopoulou, D. James Harris, Daniele Salvi, Tobias Uller. **Extensive introgression and mosaic genomes of Mediterranean endemic lizards.** *Nature Communications*, 2021; 12 (1) DOI: 10.1038/s41467-021-22949-9

A gnawing issue!

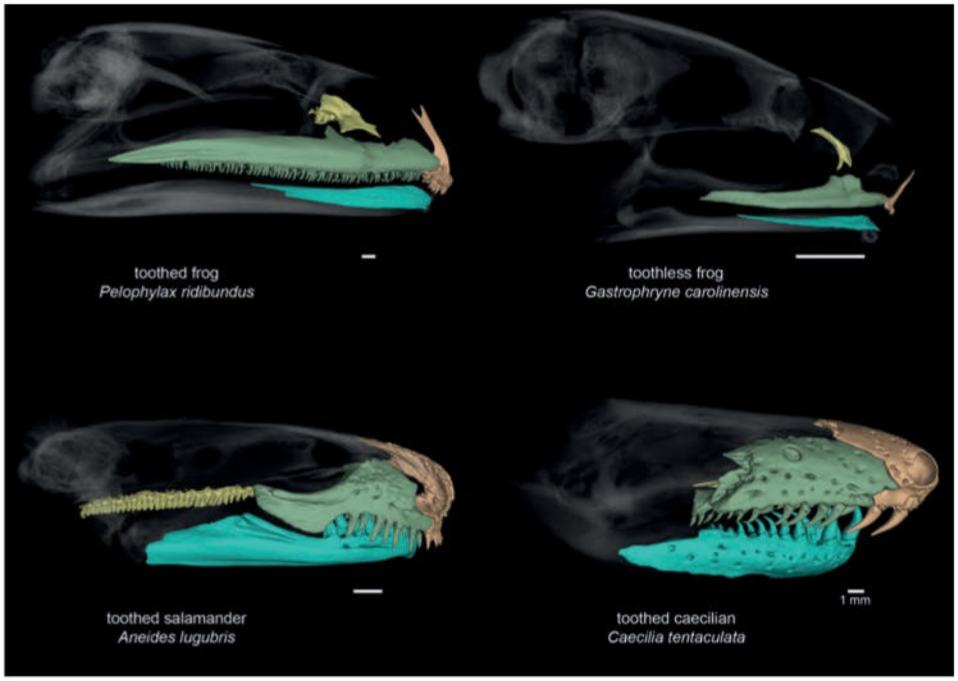
The Solomon Island leaf frog (*Cornufer guentheri*), has true teeth on its upper jaw, and bony fangs on its lower jaw which do not have any enamel or dentine, as present in teeth. Photo courtesy reptiles4all/www.shutterstock.com

Scientists have long known that frogs are oddballs when it comes to teeth. Some have tiny teeth on their upper jaws and the roof of their mouths, while others sport decidedly fang-like structures. Certain species are completely toothless, while only one frog out of the more than 7,000 known species has true teeth on both its upper and lower jaws.

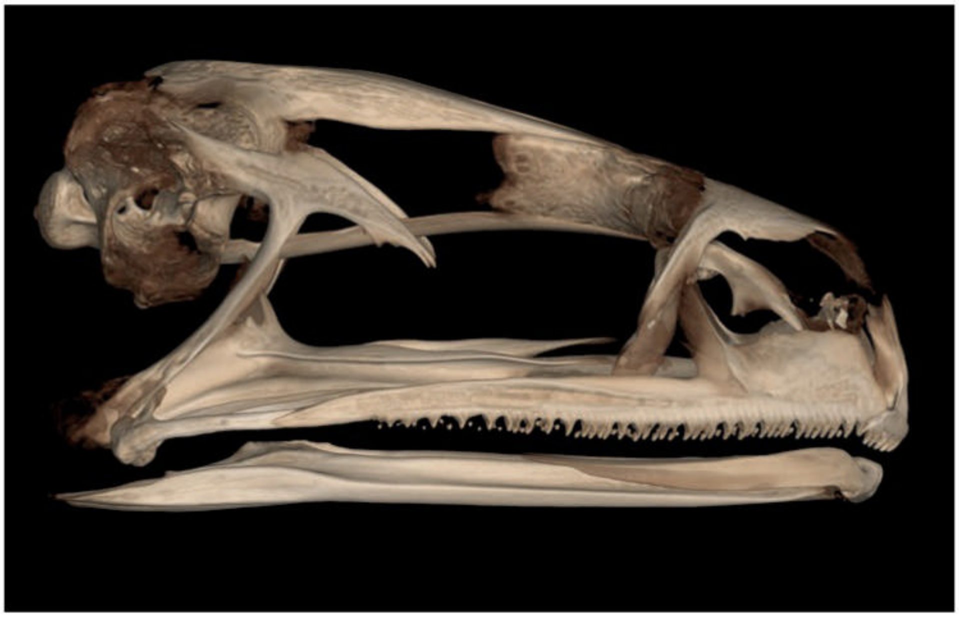
A comprehensive overview

Now, the first comprehensive study of the evolution of teeth in frogs is bringing the group's dental history into focus. Florida Museum of Natural History researchers analysed CT (computerised tomography) scans of nearly every living amphibian genus. Their study has revealed that frogs have lost teeth on over 20 occasions during their evolution, more than any other vertebrate group. Some frog species may even have re-evolved teeth after losing them millions of years beforehand.

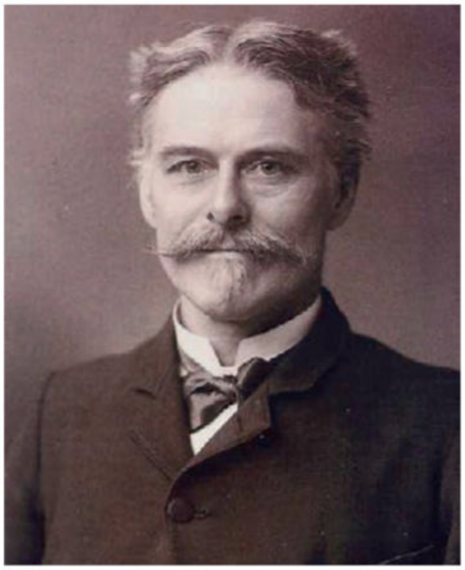
Researchers also found a correlation between the absence of teeth in frogs and a specialised diet of small insects, such as ants and termites. Their analysis of frogs'



These images showcase the dental diversity among amphibians. Salamanders and caecilians, bottom left and right, respectively, not only have teeth on both upper and lower jaws, but on the roof of their mouths as well, shown here in yellow. Photo courtesy Florida Museum/Daniel Paluh.



The group studied the teeth of virtually every living genus of frog, using CT scanning for this purpose. The green frog (*Rana clamitans*) only has teeth on its upper jaw, with none on the lower jaw. It is a common species in the eastern parts of the US, including Florida. Photo courtesy Florida Museum/Daniel Paluh.



Fossil-hunter Edward Cope used the dentition of frogs as a means of classifying them, but this method is now known to be unreliable. Photo PD.

amphibian relatives, in the guise of both salamanders and the worm-like caecilians, showed that in contrast, these groups retained teeth on both their upper and lower jaws throughout their evolutionary history.

A peculiarity of frogs

"Through this study, we have really been able to show that tooth loss in vertebrates is largely a story about frogs," says Daniel Paluh, from the University of Florida's department of biology. "Only eight other groups of living vertebrates, including seahorses, turtles, birds and a few mammals, have also evolved toothlessness."

Teeth first developed more than 400 million years ago, quickly conferring a competitive advantage to animals that had them. It led to the diversification of sharks, bony fish and ultimately the vertebrates that first roamed onto land.

Throughout the long history of vertebrates, teeth have been an important component of their evolution, yet some groups have done equally well without them. Birds lost their teeth around 100 million years ago with the advent of their bill, and both the largest known vertebrate, in the guise of the blue whale, and the smallest, a frog from New Guinea, are entirely toothless.

Few researchers have focused on studying frog teeth, however, for the simple reason that they are incredibly small. "If you open a frog's mouth, chances are you will not see teeth even if they have them, because they're usually less than a millimetre long - smaller than the tip of a pencil," says Paluh.

That hasn't stopped some people from trying! In his study of the relationships between frog species, the famous 19th-century palaeontologist Edward Cope lumped all toothless frogs into the same group, which he called Bufoniformia.

New techniques employed

Researchers using modern genetic techniques have since shown that species in Bufoniformia aren't actually closely related, which indicated that the loss of teeth occurred more than once in frog evolution. But there the story stalled.

In the past, accurately determining which frogs had teeth would have required laborious work that irrevocably damaged or destroyed portions of preserved specimens.

***Paedophryne amauensis*, a toothless species of frog native to Papua New Guinea, is the smallest known vertebrate organism.** Photo courtesy Florida Museum/Daniel Paluh.

Frogs have lost their teeth repeatedly through their evolutionary history. Photo courtesy Danny Ye/www.shutterstock.com

Frogs are also a highly diverse group, making a comprehensive assessment of their teeth a difficult task.

But Paluh and his colleagues had one major advantage: the Florida Museum leads a massive multi-institutional effort to CT scan 20,000 vertebrate specimens, giving researchers the ability to study animals in ways not previously possible. The project, called oVert, allows anyone with an internet connection to access 3D models derived from the scans.

These depict distinct features of an organism, including bones, the blood vessels, internal organs, muscle tissue – and teeth. For Paluh, it meant that he could virtually peer into the gape of a frog.

International collaboration

Working remotely during COVID-19 lockdowns, Paluh and fellow members of the museum's Blackburn Lab used oVert scans to carry out the study. In order to get the clearest picture of changes in teeth over time, the researchers included representatives of all amphibian groups. They analysed patterns of tooth loss through time using a previously published map of evolutionary relationships between amphibians based on genetic data.

The study provides a powerful example of the research that can be accomplished with open-access data, explains David Blackburn, Florida Museum curator of herpetology. "We effectively crowdsourced the data collection across our lab, even including people who were not in the US at that time," he notes.

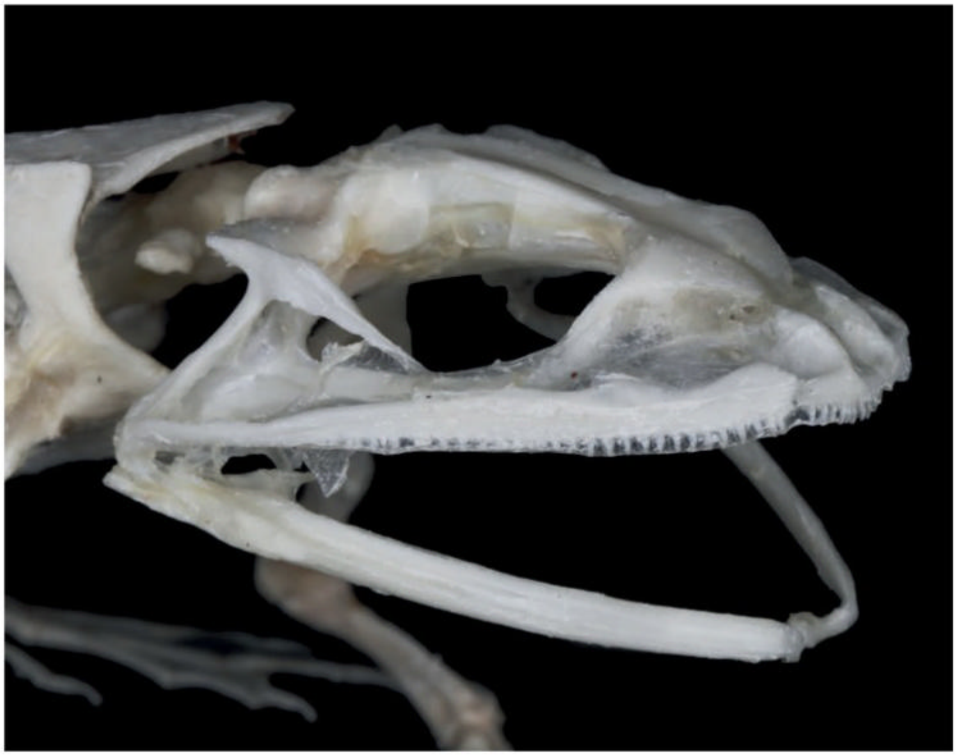
Their results showed that far from losing teeth once during their evolution, as suggested by the now-debunked idea of the Bufoniformia, frogs have undergone "rampant tooth loss," as Paluh describes it, with toothlessness popping up in groups as distantly related as toads and poison dart frogs.

Dietary links

The team also noted a tight correlation between the presence or absence of teeth in frogs and their eating habits. While dietary information is scant for many species of frog, the researchers uncovered a connection between a diet of tiny insects and a lack of teeth.

"Having those teeth on the jaw to capture and hold on to prey becomes less important because they're eating really small invertebrates that they can just bring into their mouth with their highly modified tongue," explains Paluh. "That seems to relax the selective pressures that are maintaining teeth."

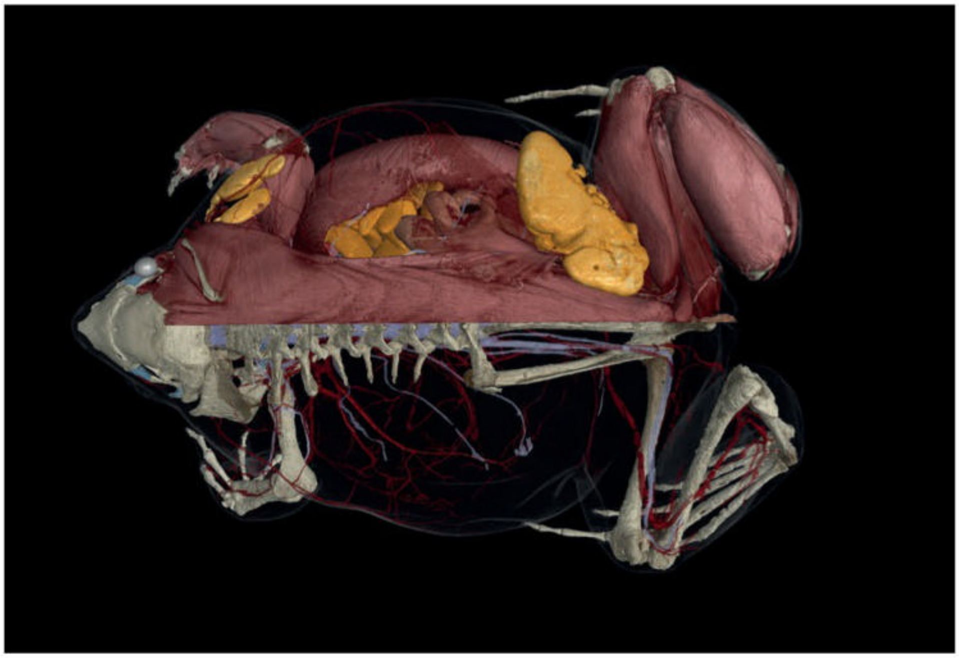
Some toothless species of poison dart frogs, for example, have evolved to feed mostly on ants and mites that produce toxic compounds, using their sticky, projectile tongues to scoop up their prey and swallow it



▲ The skull of a marsh frog (*Pelophylax ridibundus*) showing the teeth in its upper jaw. Photo courtesy photowind/www.shutterstock.com

▲ Some frogs, such as the African bullfrog (*Pyxicephalus adspersus*) seen here, are highly predatory, in terms of their feeding behaviour and can be cannibalistic, but do not have a full mouth of teeth. Photo courtesy Stu Porter/www.shutterstock.com

◄ A living example of a marsh frog. Photo courtesy colin robert varndell/www.shutterstock.com



The scans offer a unique way of studying specimens remotely. This enlarged, contrast-enhanced CT scan of a toothless Guinea snout-burrowing frog (*Hemisus guineensis*) shows muscles (pink), skeleton (tan), glands (yellow), cardiovascular system (red) and central nervous system (purple). The species feeds on ants and termites. Photo courtesy Florida Museum/Edward Stanley.

The size and type of prey has helped to shape the dental patterns of frogs. Photo courtesy Ken Griffiths/www.shutterstock.com

The highly distinctive turtle frog, photographed in the wild in the Kalbarri National Park in Western Australia. Source: https://doi.org/10.1371/journal.pone.0173348.g001 - Photo courtesy Stephen Ziozaya/PLoS ONE/CC-BY-2.5

whole. The frogs are able to store the toxins from their food source and repurpose them for their own use, secreting the compounds through their skin to ward off predators.

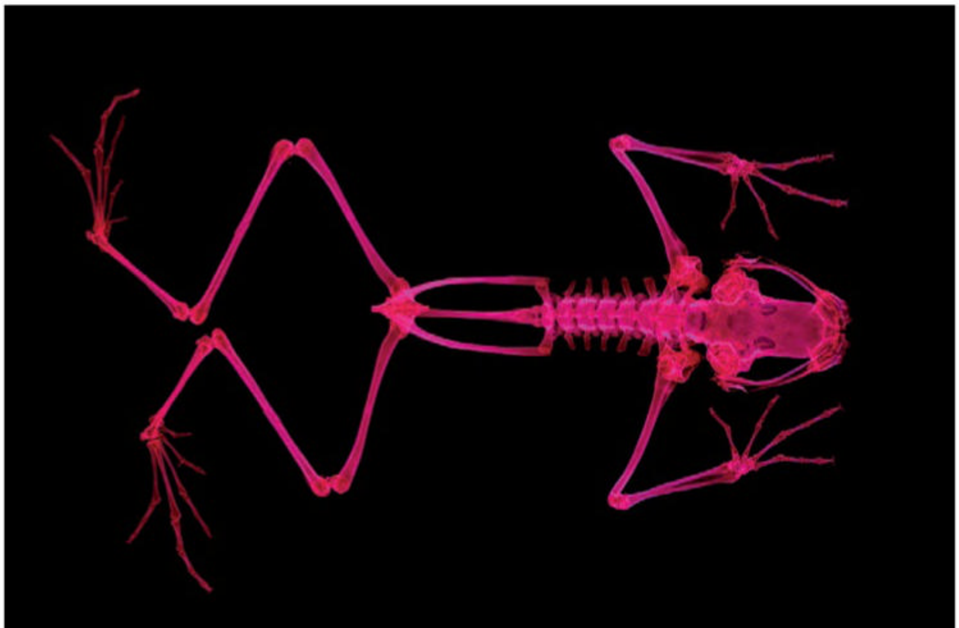
Furthermore, the turtle frog (*Myobatrachus gouldii*), a toothless burrowing species found in Australia, tunnels through the maze of underground passages inside termite nests, hunting the insects that constructed them. This corresponds to the situation with mammals, where teeth seem superfluous for those feeding on ants and termites as well. Pangolins and anteaters, which have highly specialised tongues for probing ant and termite nests, are both toothless.

Much still to discover

Many questions remain about frogs' dental biology, however, including how the genes that regulate their tooth production turn on and off. It's also unclear whether the serrated tooth-like structures in frogs that regained these features are actually real teeth, according to Paluh. In order to determine that, scientists will need to undertake a more in-depth examination of these structures, looking for the presence of enamel and other key defining features.

Innovative techniques, such as those used in the oVert project, are beginning to underscore knowledge gaps and limitations like these, but they also open up the field to further discoveries.

"We now have lots of new questions in my lab inspired by the surprising things turning up as a result of 3D imaging from the oVert project, and those will lead us both back into museum collections and to the field, to see what these animals are doing in the wild," adds David Blackburn.

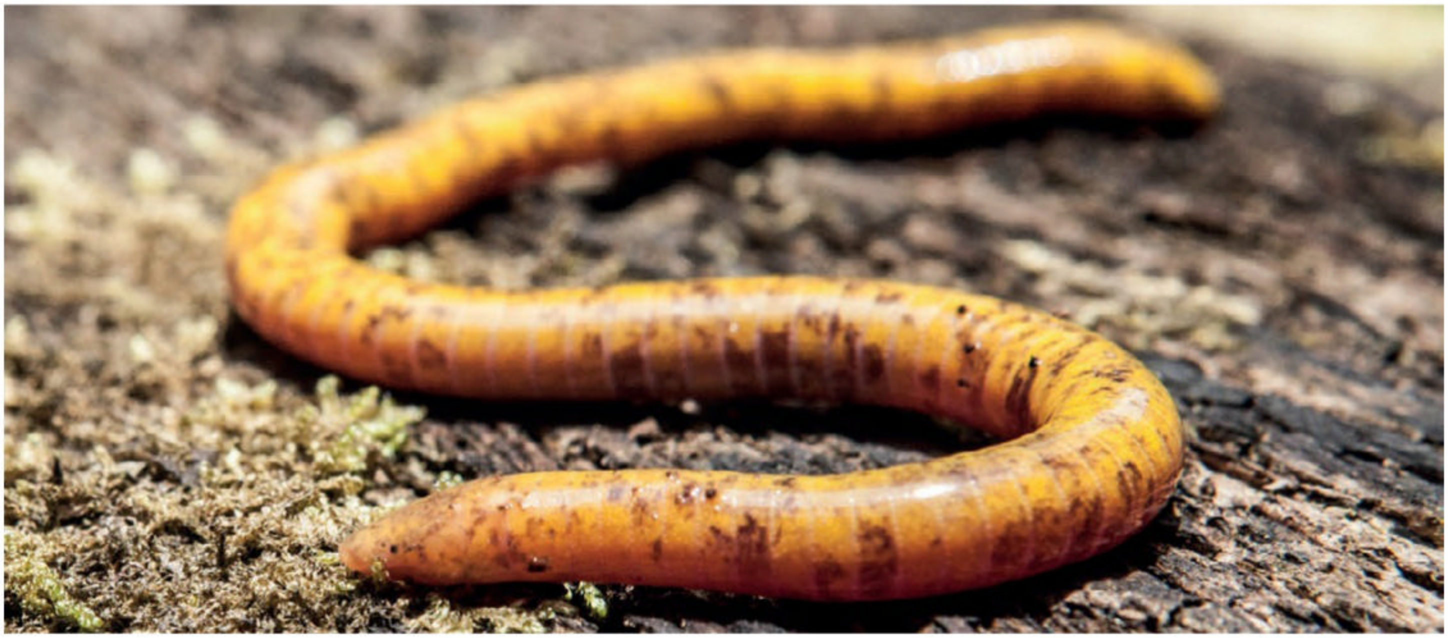


The strawberry poison frog (*Oophaga pumilio*) is a toothless species that eats ants and termites.

Further information

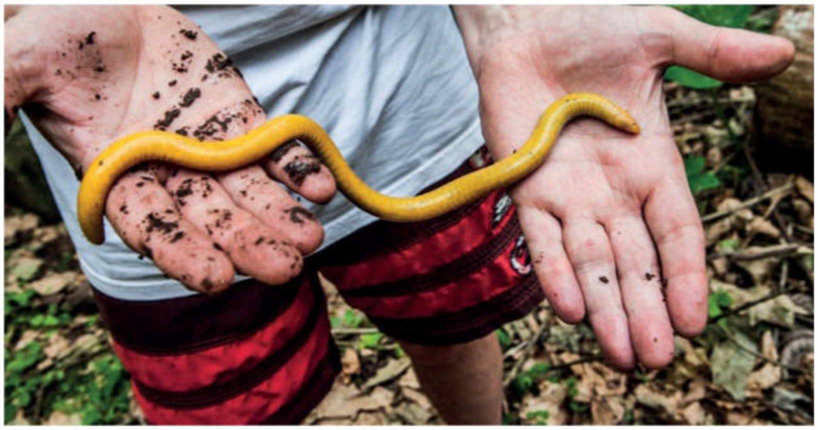
Daniel J Paluh, Karina Riddell, Catherine M Early, Maggie M Hantak, Gregory FM Jongsma, Rachel M Keeffe, Fernanda Magalhães Silva, Stuart V Nielsen, María Camila Vallejo-Pareja, Edward L Stanley, David C Blackburn. **Rampant tooth loss across 200 million years of frog evolution.** *eLife*, 2021; 10 DOI: 10.7554/eLife.66926

Unique findings on São Tomé island



⮝ **A mottled São Tomé caecilian.** Photo © Andrew Stanbridge.

The islands located in the Gulf of Guinea harbour an abundance of species found nowhere else on Earth. But for over 100 years, scientists have wondered whether or not a population of limbless, burrowing amphibians—known as caecilians—found on one of the islands is a single or multiple species.



⮝ **The pure lemon-yellow form occurs in northern areas of the island.** Photo © Andrew Stanbridge.

Guinea Gulf
NIGERIA
CAMEROON
GABON
CONGO
ANGOLA
ZAMBIA
ZIMBABWE
NAMIBIA
BOTSWANA
SOUTH AFRICA
LESOTHO
LIBERIA
GHANA
EQUATOR
TROPIC OF CAPRICORN
Cape Town

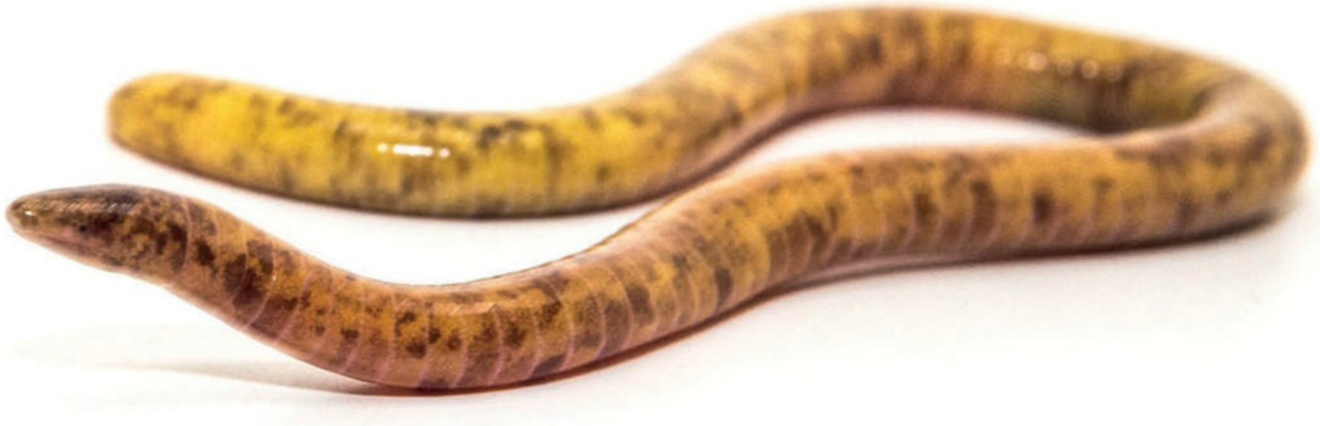
⮟ **São Tomé lies south of Nigeria in the Gulf of Guinea.** Photo courtesy TonelloPhotography/www.shutterstock.com

Divided into two

Now, a team of researchers from the California Academy of Sciences and the Smithsonian National Museum of Natural History has contributed the strongest evidence to date that there is not one, but two different species of caecilians present on São Tomé. Their research also suggests that volcanic activity may have led to the divergence of the original species.

"To judge whether one species is in fact composed of multiple lineages, scientists have to build a case," explains Academy Curator of Herpetology Rayna Bell. "By conducting a population level genomic study of these amphibians across the entire island, we are adding a crucial line of evidence that the São Tomé caecilian is actually two unique species."

Initially described by Portuguese scientists during colonial times, the São Tomé caecilians were later split



into two distinct species based on their variation in colour and location on the island—solid lemon-yellow in the north and yellow with brown splotches to the south. Since then, subsequent research has bounced back and forth, grouping the species together then separating them out again, based on the best available evidence.

New insights

Recently, a study by former Academy Curator of Herpetology Robert Drewes and Ricka Stoelting using mitochondrial DNA indicated that not only were they likely to be two unique species, but they might be interbreeding. Bell and her colleagues then build upon those previous findings by sampling 85 caecilians from 21 locations across the island for genome-wide genetic markers that more accurately confirm the presence—and interbreeding—of the two species.

"That earlier study was the first clue towards unraveling the mystery of the São Tomé caecilians," Bell explains. "Our study provides further proof of the presence of two separate, interbreeding species and quantifies how much overlap—or hybridisation—is occurring between them."

Once the research team confirmed the existence of two different but interbreeding species, they started to work backward through time to try to determine how the species diverged. "It's pretty remarkable that there are two unique species on such a small island," says Academy collections manager Lauren Scheinberg. "It really makes you wonder how natural selection is acting to drive speciation."

The time-frame

Through their analysis, the researchers found that the two species diverged around 300,000 years ago, which is a time period that coincides with a burst of volcanic activity on the island. The researchers suggest that lava flows during this period may have led to the speciation of the caecilians by dividing the island into a patchwork of smaller habitats with unique environmental pressures. As the lava flows eroded, resulting in suitable habitat for caecilians, the two species then came back into contact and started to hybridise, obscuring the evidence of their separation.

"These findings are an important reminder that islands are not static," Bell says. "Even though they can be small and isolated, they are dynamic systems that are actively accumulating new species. It's also an important consideration for the conservation of São Tomé caecilians to know that we have two, genetically and morphologically unique species."

New challenges

Though the picture of their past is becoming clearer, there is still much to learn about these enigmatic amphibians. For example, while most caecilians spend a majority of their time underground, the São Tomé caecilians can be readily found on the forest floor, raising questions about how the bright yellow amphibians avoid predation.

While one century-long mystery is nearing a resolution, it seems more are taking its place. But Bell is looking forward to the challenge. "These are perhaps the most well-studied caecilians on Earth because of their accessibility and how long ago they were first described by science. Yet there is still so much to learn about them, from their mating behaviour to how they deter predators," Bell says. "For a biologist, what could be more exciting than that?

➤ Evidence of volcanic activity on the island is still apparent in the landscape. This is Pico Cão Grande, a needle-shaped volcanic plug, which towers 370 m (1,210 ft) over the surrounding countryside.
Photo courtesy alfotokunst/ www.shutterstock.com

Further information

Kyle A. O'Connell, Ivan Prates, Lauren A. Scheinberg, Kevin P. Mulder, Rayna C. Bell. **Speciation and secondary contact in a fossorial island endemic, the São Tomé caecilian.** *Molecular Ecology*, 2021; DOI: 10.1111/mec.15928

It could be that being brightly coloured, predators regard these caecilians are being toxic, and so do not molest them. Photo © Andrew Stanbridge.

Sea snakes have a sensitive side!

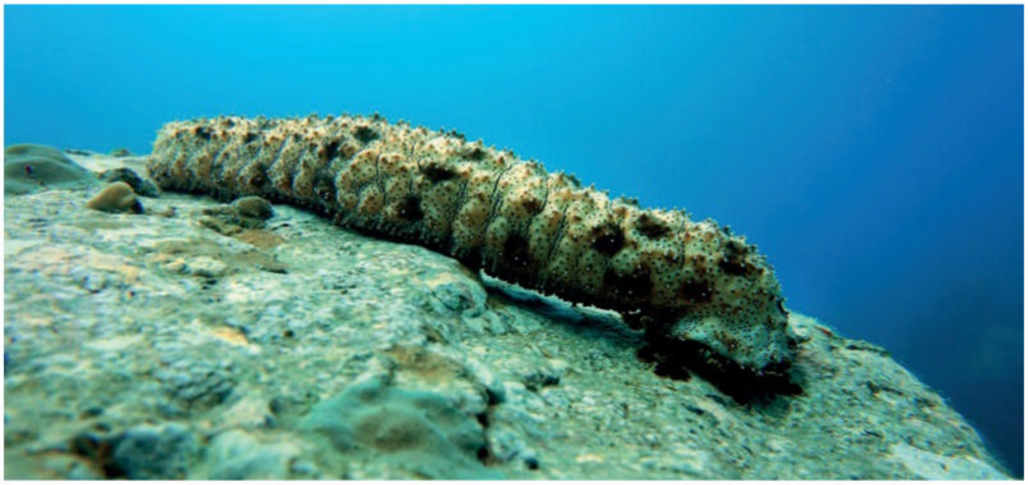
Photo courtesy Jack Pokoj/www.shutterstock.com

Decades of research have revealed the remarkable anatomical adaptations of sea snakes to aquatic life, which include paddle-shaped tails, salt-excreting glands, and the ability to breathe through their skin. In addition to this list, researchers at the University of Adelaide in Australia have now found enlarged touch receptors that evolved in male turtle-headed sea snakes (*Emydocephalus annulatus*), in order to help them locate and court females in the ocean.

The need for different modes of communication

Jenna Crowe-Riddell, from the School of Biological Sciences, explains that on land, snakes use tongue-flicking to sense and follow sex pheromones left by other snakes, but in the water, such chemicals are diluted.

“What’s more, turtle-headed sea snakes can’t see very clearly underwater; they’ve been known to court anything long and dark, including sea cucumbers. To make matters worse, once a female is found the male must overcome buoyancy force so he doesn’t float away from his potential mate,” she explains.



⮝ The poor vision of sea snakes has led to them being observed courting sea cucumbers. Photo courtesy Natalia Siiatovskaia/www.shutterstock.com

“When we took a closer look at museum specimens, we discovered male turtle-headed sea snakes have larger touch receptors overall than females. We also found mature males have enlarged scale structures on their snout and chin, and their cloaca — an all-purpose opening used for reproduction and excretion."

Specialist touch-receptors

Crowe-Riddell and colleagues used a range of microscopy techniques to characterise the features of the enlarged scale structures seen in these sea snakes. They found that the structures on the chin and cloaca have specialised cells indicative of touch receptors – which suggests they provide sensory feedback for the male.

"Most snakes have thousands of touch receptors all over their face that look like a dusting of freckles. These touch receptors have become much larger in sea snakes, potentially to sense vibrations made by swimming mates, prey or predators."

The researchers suggest that chin receptors may help males orient towards the direction of the female's swimming, whereas the cloacal receptors may help the male to align himself for successful reproduction.

"We think these receptors evolved to help males maintain the correct points of contact with the female during mating, which is a tricky task when you're a tube-shaped, limbless snake," explains Crowe-Riddell. Males also have a spine-like structure on the snout known as a 'rostral spine' that is used to prod the back of females during courtship.

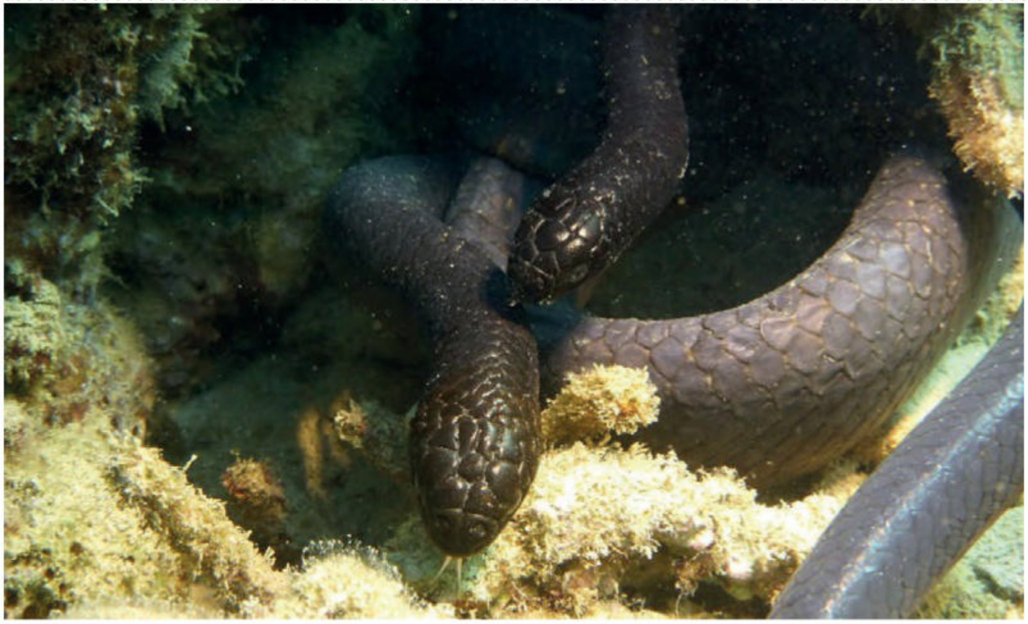
The need for change

"The rostral spine may be used to stimulate the female. Such types of tactile foreplay are thought to be important for mating in snakes because they can cause beneficial hormonal changes and receptive behaviours in females," she adds.

"Reptiles are not typically appreciated for their intimate interactions, but our research is revealing that sea snakes have fascinating tactile adaptations for intra-species communication."

The evolutionary transition from terrestrial to aquatic life has influenced the signalling systems of many secondarily aquatic animals. "As we build a more complete picture of underwater perception, sea snakes are becoming a fantastic example of how evolution creates opportunity from constraints," Crowe-Riddell concludes.

Further research could examine the role that tactile sensory modalities play in mate selection, an often-overlooked aspect of snake social behaviour. There are at least three species of turtle-headed sea snake, occurring in shallow-water habitats in Australia, south-east Asia and the Indo-Pacific. In this study, researchers examined 59 specimens collected from offshore reefs in the Timor Sea, and accessed from the Australian Museum, the Art Gallery of Northern Territory, and the Western Australian Museum.



⮝ Male and female turtle-headed sea snakes in a mating coil. The smaller male uses a modified scale on the snout to prod at the back of the female.
Photo courtesy Jenna Crowe-Riddell.

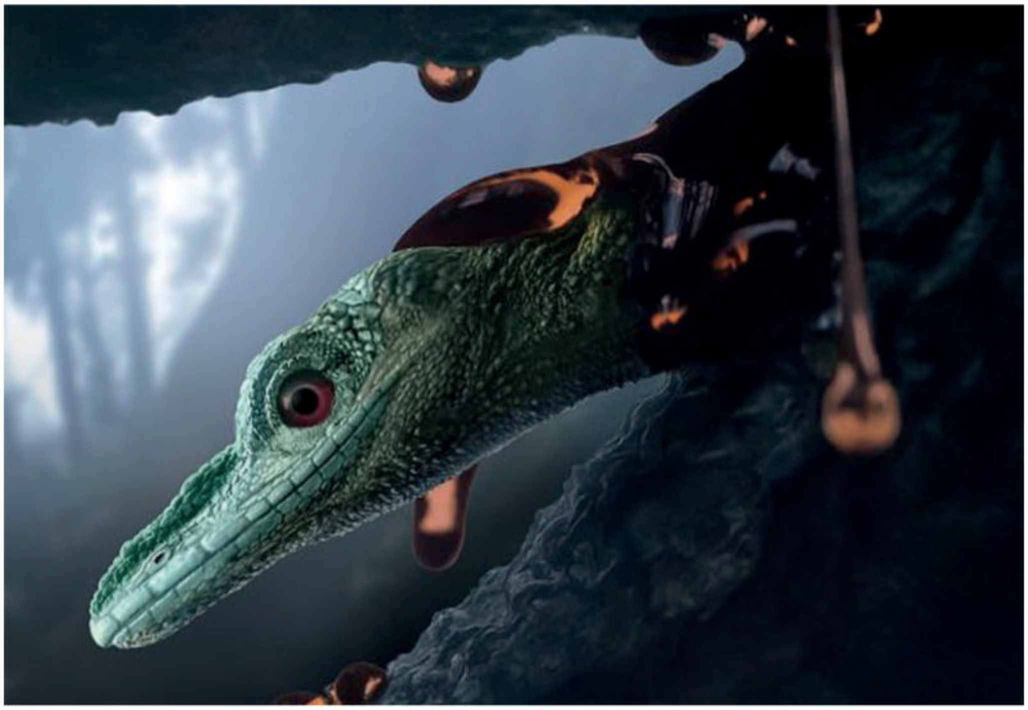
⮟ A paddle-shaped tail to assist swimming is a feature seen in sea snakes. Now it appears that touch receptors help males to interact at close quarters with females.
Photo courtesy Gabriel Guzman/www.shutterstock.com

⮝ Direct touch is thought important in sea snakes to trigger hormonal changes in the female's body, and ultimately mating.
Photo courtesy paul cowell/www.shutterstock.com

Further information

Jenna M Crowe-Riddell, Chris J Jolly, Claire Goiran, Kate L Sanders. **The sex life aquatic: sexually dimorphic scale mechanoreceptors and tactile courtship in a sea snake *Emydocephalus annulatus* (Elapidae: Hydrophiinae).** *Biological Journal of the Linnean Society*, 2021; DOI: 10.1093/biolinnean/blab069

Tiny lizard's identity confirmed



Amber preserved fine anatomical details of *Oculudentavis naga*, including scales on its chin and around its nostril. Researchers estimate the lizard was between 5-7.5cm (2-3in) long, excluding its tail. Photo courtesy Stephanie Abramowicz/Peretti Museum Foundation/Current Biology.

An international research team has described a new species of *Oculudentavis*, providing further evidence that the creature first identified as a hummingbird-sized dinosaur was actually a lizard. The new species, named *Oculudentavis naga* in honour of the Naga people of Myanmar and India, is represented by a partial skeleton that includes a complete skull, exquisitely preserved in amber with visible scales and soft tissue.

The specimen is in the same genus as *O. khaungraae*, whose original description as the smallest known bird, published by a different group of researchers, was retracted last year. The two fossils were found in the same area and both are about 99 million years old.

Preserved as an amber fossil

The team, led by Arnau Bolet of Barcelona's Institut Català de Paleontologia Miquel Crusafont, used CT scans to separate, analyse and compare each bone in the two species digitally, uncovering a number of physical characteristics that earmark the small animals as lizards. *Oculudentavis* is so strange, however, that it was difficult to categorise without close examination of its features, accordingly to Bolet.

"The specimen puzzled all of us at first because if it was a lizard, it was a highly unusual one," he says. Bolet and fellow lizard experts from around the world first noted the specimen while studying a collection of amber fossils acquired from Myanmar by gemologist Adolf Peretti.

CHINA
THIMPHU
BHUTAN
INDIA
CHINA
BANGLADESH
DHAKA
Putao
Myitkyina
Bhamo
Mogok
Shwebo
Lashio
Monywa
Mandalay
MYANMAR
(BURMA)
Taunggyi
Magway
NAYPYIDAW
LAOS
VIETNAM
Prome
VIENTIANE
Bay of Bengal
Bago
Yangon
Hpa-An
THAILAND
Dawei
BANGKOK
CAMBODIA
Andaman and Nicobar Islands (INDIA)
Myeik
Myeik Archipelago
ANDAMAN SEA
Gulf of Thailand

Myanmar used to be known as Burma, and lies in south-east Asia. Map courtesy Peter Hermes Furian/www.shutterstock.com

While the mining and sale of Burmese amber are often entangled with human rights abuses, Peretti purchased the fossil legally prior to the conflict in 2017.

What was the mysterious creature?

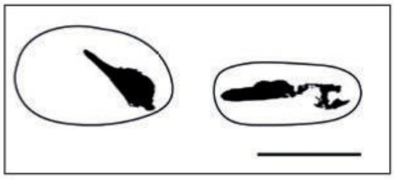
Herpetologist Juan Diego Daza examined the small, unusual skull, which was preserved with a short portion of the spine and shoulder bones. He, too, was confused by its odd array of features: could it be some kind of pterodactyl or possibly an ancient relative of monitor lizards?

"From the moment we uploaded the first CT scan, everyone was brainstorming what it could be," admits Daza, assistant professor of biological sciences at Sam Houston State University in the US. "In the end, a closer look and our analyses help us clarify its position."

Researchers began analysing the unusual lizard in 2019, which was the year before a separate team published a paper misidentifying a similar fossil as the smallest avian dinosaur ever found. Taken together, the two species most likely represent a previously unknown group of scaled reptiles.

Clues to its identity

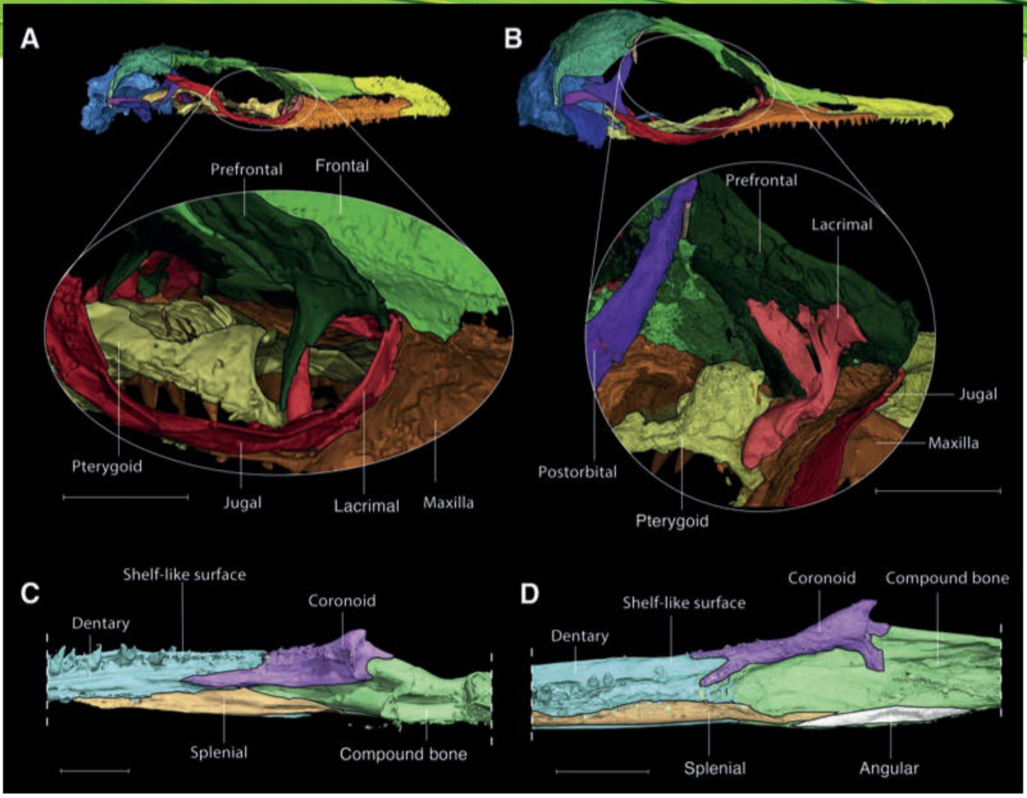
Major clues that the mystery animal was a lizard included the presence of scales; teeth attached directly to its jawbone, rather than nestled in sockets, as dinosaur teeth were; lizard-like eye structures and shoulder bones; and a hockey stick-shaped skull bone that is universally shared among scaled reptiles, known as squamates.



It is easy to see why confusion initially arose about the identity of the two fossils, with one closely resembling a bird while the other looked more like a lizard. The scale bar accompanying this diagram is equivalent to 2cm. *O. naga* is portrayed on the right. Artwork SivrHwk/wikipedia/CC BY-SA 4.0

The team also determined both species' skulls had deformed during preservation. *Oculudentavis khaungraae*'s snout had been squeezed into a narrower, more beak-like profile while *O. naga*'s braincase – the part of the skull that encloses the brain – was compressed.

The distortions highlighted features in common with a bird in one case and those associated with lizards in the other, according to Edward Stanley, director of the Florida Museum of Natural History's Digital Discovery and Dissemination Laboratory. "Imagine taking a lizard and pinching its nose into a triangular shape,"



▲ As researchers digitally isolated each bone, shown in a rainbow of colours here, the similarities between *Oculudentavis naga*, (left), and *O. khaungraae* came into focus. The lizards' tapered narrow snout looks deceptively like a beak in appearance, an effect heightened by a well-developed crest, explains herpetologist Juan Diego Daza. Image courtesy Edward Stanley of the Florida Museum. Adapted from *Current Biology*, with CT scans funded by the Peretti Museum Foundation.

▼ Amber often preserves small forest animals, capturing a valuable snapshot of life in ecosystems that otherwise break organic material down quickly, says herpetologist and CT expert Edward Stanley. Image courtesy Edward Stanley of the Florida Museum. Adapted from *Current Biology*, with CT scans funded by the Peretti Museum Foundation.

▲ Ancient insects are more commonly found in amber, which is solidified ancient sticky tree sap, than small lizards. Photo courtesy Ernie Cooper/www.shutterstock.com

Stanley says. "It would look a lot more like a bird."

Oculudentavis' bird-like skull proportions, however, do not indicate that it was related to birds, notes Susan Evans, professor of vertebrate morphology and palaeontology at University College London. "Despite possessing a vaulted cranium and a long, tapering snout, it does not present meaningful physical characters that can be used to sustain a close relationship to birds, and all of its features indicate that it is a lizard," she says.

A relationship emerges

While the two species' skulls do not closely resemble one another at first glance, their shared characteristics became clearer as the researchers digitally isolated each bone and compared them with each other. The differences were minimised when the original shape of both fossils was reconstructed through a painstaking process known as retrodeformation, conducted by Marta Vidal-García from the University of Calgary in Canada.

"We concluded that both specimens are similar enough to belong to the same genus, *Oculudentavis*, but a number of differences suggest that they represent separate species," Bolet says.

In the better-preserved *O. naga* specimen, the team was also able to identify a raised crest running down the top of the snout and a flap of loose skin under the chin that may have been inflated for display purposes. However, the researchers came up short in their attempts to find *Oculudentavis*' exact position in the lizard family tree.

No clearly-defined links

"It's a really weird animal. It's unlike any other lizard we have today," Daza acknowledges. "We think it represents a group of squamates (within the lizard sub-group) that we were not previously aware of."

The Cretaceous Period, extending from roughly 145.5 to 66 million years ago, gave rise to many lizard and snake groups still alive on the planet today, but tracing fossils from this era to their closest living relatives can be difficult, according to Daza.

"We estimate that many lizards originated during this time, but they still hadn't evolved their modern appearance," he says. "That's why they can trick us. They may have characteristics of this group or that one, but in reality, they don't match perfectly."

Seeking others's involvement

The majority of the study was conducted with CT data created at the Australian Centre for Neutron Scattering and the High-Resolution X-ray Computed Tomography Facility at the University of Texas at Austin. *Oculudentavis naga* is now available digitally to anyone with Internet access, which allows the team's findings to be reassessed and opens up the possibility of new discoveries, Stanley says.

"With palaeontology, you often have one specimen of a species to work with, which makes that individual very important. Researchers can therefore be quite protective of it, but our mindset is: 'Let's put it out there,'" Stanley acknowledges. "The important thing is that the research gets done, not necessarily that we do the research. We feel that's the way it should be."

There are issues, however, in research in this part of the world. While Myanmar's amber deposits are a treasure trove of fossil lizards found nowhere else in the world, Daza explains that the consensus among palaeontologists is that acquiring Burmese amber ethically has become increasingly difficult, especially after the military seized control in the country again in February 2021.

"As scientists we feel it is our job to unveil these priceless traces of life, so the whole world can know more about the past. But we have to be extremely careful that during the process, we don't benefit a group of people committing crimes against humanity," he says. "In the end, the credit should go to the miners who risk their lives to recover these amazing amber fossils."

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Bolet, A.; Stanley, E. L.; Daza, J. D.; Salvador Arias, J.; Čerňanský, A.; Vidal-García, M.; Bevitt, J. J.; Peretti, A.; Evans, S. E. (2021). **Unusual morphology in the mid-Cretaceous lizard *Oculudentavis*.** *Current Biology*: 14 June 2021. doi:10.1016/j.cub.2021.05.040.

SNAKE-KILLING SPIDERS

A snake entrapped and killed in a black widow web in the corner of the front porch of a house in Gulf Breeze, Florida, USA.
Photo courtesy Trisha Haas.

It has long been known that some spiders eat snakes, with observations of this behaviour having been reported from around the world. Now, to gain better overall insight into this phenomenon, Dr Martin Nyffeler, an arachnologist at the University of Basel in Switzerland, and American herpetologist Professor Whitfield Gibbons of the University of Georgia in the USA have consolidated and analysed over 300 reports of this unusual behaviour.

Their study reveals that on every continent where snakes are found, there are reports of them being eaten by spiders. Spiders are primarily insectivores, but they can be opportunistic hunters and occasionally expand their menu by catching and eating small snakes. Interestingly, eighty percent of the incidents reported were observed in the US and Australia.

In Europe, on the other hand, this behaviour has been only observed very rarely, accounting for less than one percent of all reported cases. In addition, it is limited to the consumption of tiny, non-venomous snakes of the blind snake family (Typhlopidae) by small web-building spiders. A possible explanation is that Europe's native colubrids and vipers are too big and heavy even when newly-hatched, so that spiders there cannot subdue them.

Black widows are most successful

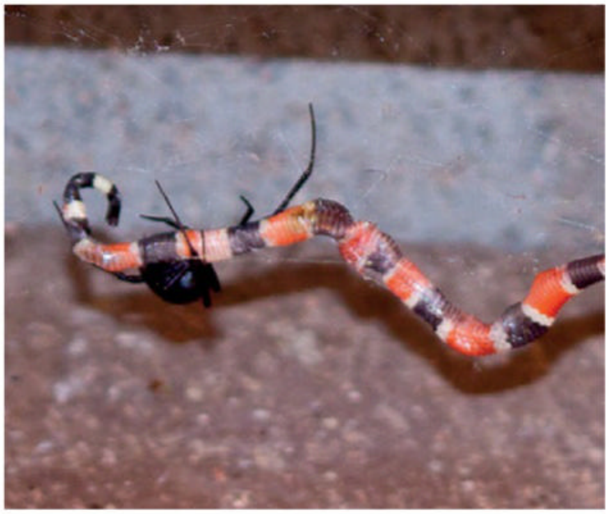
Overall, the data analysis revealed that spiders from 11 different families are able to catch and eat snakes. "That so many different groups of spiders sometimes eat snakes is a completely new finding," admits Nyffeler.

It emerged that black widows of the family Theridiidae were the most successful snake hunters, being involved in about half of all observed incidents. Their potent venom contains a toxin that specifically targets the nervous systems of vertebrates. These spiders also build webs composed of extremely tough silk, allowing them to ensnare and capture larger prey animals like lizards, frogs, mice, birds and snakes.

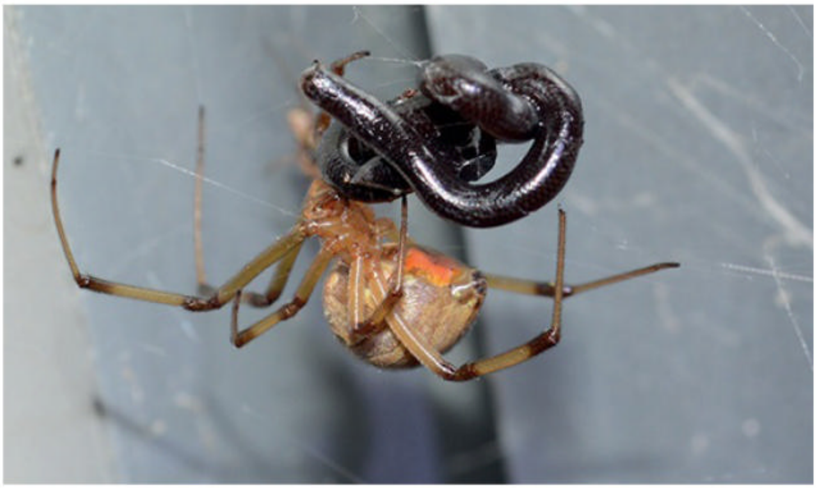
Big catch

Some remarkable new findings emerged from this study. Spiders can subdue snakes from seven different

⮟ Juvenile snake entrapped on the web of a black widow (*Latrodectus* species), observed in a private residence in Georgia, USA.
Photo courtesy Daniel R. Crook.



⮝ **Adult female black widow feeding on a venomous subadult coral snake in Superior, Arizona, USA.** Photo courtesy Lawrence L. C. Jones.

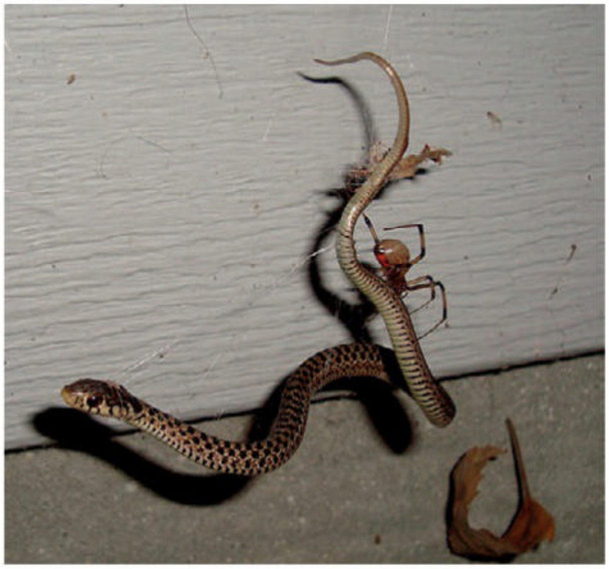


⮝ **Brown widow spider feeding on a Brahminy blindsnake (*Indotyphlops braminus*) in a garden house in Zaachila, Oaxaca, Mexico.** Photo courtesy Matias Martinez.

families. They can even outfight snakes between 10 and 30 times their size. The largest snakes caught by spiders were up to 1m (39in) in length, with the smallest measuring about 6cm (2.4in).

According to the statistical analysis carried out by the two researchers, the average length of captured snakes was 26cm (10.2in). Most of the snakes caught were very young. That some spiders are able to subdue oversized prey is attributable to their highly potent neurotoxins and strong, tough webs.

⮞ **This is what is left when the ants descend on the remains of the dead snake. Observed in Douglas, Georgia, USA.** Photo courtesy Julia Safer.



⮟ **Juvenile eastern garter snake (*Thamnophis sirtalis*) trapped in a brown widow web (*Latrodectus geometricus*) observed in Douglas, Georgia, USA.** Photo courtesy Julia Safer.

Possible insights into the effect of spider venom

Many species of spider that occasionally kill and eat snakes have venom that can also be lethal to humans. That means the venom of various spider species has a similar effect on the nervous systems of snakes and humans. For this reason, observations of vertebrate-eating spiders can also be important for neurobiology, as they allow conclusions to be drawn about the mechanisms by which spider neurotoxins affect vertebrate nervous systems.

"While the effect of black widow venom on snake nervous systems is already well researched, this kind of knowledge is largely lacking for other groups of spiders. A great deal more research is therefore needed to find out what components of venoms that specifically target vertebrate nervous systems are responsible for allowing spiders to paralyse and kill much larger snakes with a venomous bite," says Martin Nyffeler.

The captured snakes are anything but helpless themselves: about 30 percent are venomous. In the US and South America, spiders sometimes kill highly venomous rattlesnakes and coral snakes. In Australia, brown snakes (*Pseudonaja* species) – which belong to the same family as cobras – often fall prey to redback spiders (Australian black widows). Martin Nyffeler explains: "These brown snakes are among the most venomous snakes in the world and it's really fascinating to see that they lose fights with spiders."

Storage of energy reserves

When a spider catches a snake, it will often spend hours or days feasting on such a large prey. Spiders have an irregular feeding pattern. When a lot of food is available, they eat in excess, only to go hungry for long periods again afterward. They store excess food as energy reserves in their body and use it to tide them over longer periods of starvation. Nevertheless, a spider often eats only a small part of a dead snake. Scavengers such as ants, wasps and flies consume whatever remains.

Further information

Martin Nyffeler, J. Whitfield Gibbons. **Spiders (Arachnida: Araneae) feeding on snakes (Reptilia: Squamata).** *The Journal of Arachnology*, 2021; 49 (1) DOI: 10.1636/JoA-S-20-050

Rattlesnakes may benefit from global warming

⮝ **Rattlesnakes could benefit from warmer surroundings. This is a Great Basin rattlesnake (*Crotalus oreganus lutosus*).** Photo courtesy Matt Jeppson/ www.shutterstock.com

➤ **Former Cal Poly undergraduate Mallory Harmel radiotracks rattlesnakes at Montaña de Oro State Park on a foggy morning.** Photo courtesy Hayley Crowell.

When it comes to climate change, not all organisms will lose out. A new Cal Poly study indicates that rattlesnakes are likely to benefit from a warming climate, for a variety of reasons. Rattlesnakes themselves are found in almost every part of the continental United States but are especially common in the southwest region.

Temperature preferences

Rattlers are experts at thermoregulation. Researchers found that, when given a choice, the snakes prefer a body temperature of 30-31.6°C (86-89°F), a much warmer temperature than they generally experience in nature. The average body temperature of coastal rattlesnakes in the study was 21°C (70°F) degrees, and for inland rattlers it was 23°F (73°F).

"We were surprised to see how much lower the body temperatures of wild snakes were relative to their preferred body temperatures in the lab," says Hayley Crowell, who led the research. "There are a lot of ecological pressures in nature that could prevent rattlesnakes from basking, such as the risk of increased exposure to predators. A warmer climate may help these snakes heat up to temperatures that are more optimal for their digestion or reproduction."

Longer periods of warmer temperatures would also give rattlesnakes a more prolonged active season, providing them with more time to hunt and feed. Since snakes are ectothermic, or cold-blooded, they cannot regulate their body temperatures like warm-blooded animals. Instead, they rely on their surroundings to provide heat, which restricts their activity in cold weather.

In addition to seasonal changes, rattlers could be active for longer during the day on this basis.

A lower calorific requirement

A possible lack of prey — rattlesnakes eat mostly rodents, but may also hunt insects and other reptiles — resulting from a warming climate may not be a big problem for the snakes either. The research team discovered that the

⮝ Rattlesnakes may hunt for longer if the climate warms up. Photo courtesy Michael Benard/www.shutterstock.com

snakes use energy extremely efficiently. In order to subsist, an adult male rattlesnake needs only 500-600 calories for an entire year, which is about one ground squirrel and the equivalent of only about half a large burrito!

In the real world, a rattler also needs additional calories to hunt and have young among other activities, but the calculations nevertheless point to the snakes' ability to survive even if prey isn't plentiful. Humans, by comparison, need about 1,300 times as many calories to survive!

Rattlesnakes are widespread throughout California, and the seven species of these vipers in the Golden State can be found in environments ranging from the coast to the desert. An increase in the number of snakes could affect entire ecosystems. Rattlesnakes are a keystone predator for ground squirrels in California and are themselves prey for raptors and many other animals.

"Rattlesnakes require very little energy to exist," says Crowell. "We are so used to climate change studies that forecast negative impacts on wildlife — it was interesting to see such starkly different findings for these snakes."

CAUTION
RATTLESNAKES
IN
BUSHES

An increase in rattlesnake numbers could lead to greater conflict with people. Photo courtesy Albert Campbell/www.shutterstock.com

Further information

Hayley L. Crowell, Katherine C. King, James M. Whelan, Mallory V. Harmel, Gennesee Garcia, Sebastian G. Gonzales, Paul H. Maier, Heather Neldner, Thomas Nhu, John T. Nolan, Emily N. Taylor. **Thermal ecology and baseline energetic requirements of a large-bodied ectotherm suggest resilience to climate change.** *Ecology and Evolution*, 2021; 11 (12): 8170 DOI: 10.1002/ece3.7649

How studies don't always work out!

An eastern spadefoot toad, revealing its yellowish eyes, photographed in the state of Illinois. Photo courtesy Jason Patrick Ross/www.shutterstock.com

⮝ These frogs are well-concealed in their environment and adept at burrowing, but spend far less time underground than used to be thought. Photo courtesy jcohen9/www.shutterstock.com

Research by Oregon State University's College of Science has upended conventional wisdom that had previously stood unchallenged for a century, and incorrectly guided the study of a toad listed as endangered in part of its range.

Anne Devan-Song used spotlighting – shining a light in a dark spot and looking for eye reflections – to find large numbers of the eastern spadefoot toad (*Scaphiopus holbrooki*). The study illustrates how confirmation bias – a tendency to interpret new information as an extension of existing theories – can hamper discovery and the development of more accurate information. Her findings have surprisingly revealed that the toad spends much more time above ground than commonly believed.

Lifestyle

Known for yellow eyes with elliptical pupils and, as the name suggests, equipped with what is basically a spade on each hind foot to assist its digging ability, the eastern spadefoot toad ranges from the southeast corner of the United States up the Atlantic Coast to New England, where it is endangered in the northern part of its territory.

It took a fresh approach to make this discovery, with Devan-Song growing up in Singapore, where she learned she could search for reptiles and amphibians by spotlighting. During a rainless night while surveying for amphibians as part of a project in Virginia, Devan-Song's spotlight detected one eastern spadefoot after another. That surprised her because the toads were thought to be detectable

CANADA
MAINE
Mt Desert I.
Gulf of Maine
VERMONT
NEW HAMPSHIRE
New York
MASSACHUSETTS
Cape Ann
ATLANTIC
OCEAN
Cape Cod
CONNECTICUT
RHODE ISLAND
Block I.
Martha's I.
Nantucket I.
Long Island Sound
New York

⮝ The state of Rhode Island lies in the northeastern part of the USA.
Map courtesy Rainer Lesniewski/www.shutterstock.com

⮝ A spadefoot hiding amongst pebbles. Even in the open, these are not conspicuous amphibians, and tracking them with torchlight gives the best insight into their numbers in an area.
Photo courtesy Randy Bjorklund/www.shutterstock.com

only on a few rainy nights every year, when they emerge from underground burrows to mate in wetlands.

She continued looking for eastern spadefoots and kept finding them on dry nights, including in upland forest localities not close to any damp areas. Spadefoots remain still when spotlighted so it was easy for Devan-Song to approach the eyeshines and positively identify the toads.

"They need to get above ground to hunt for insects and build up energy stores for mating," she explains. "That's why we were finding them when and where conventional wisdom said we weren't supposed to be!"

⮟ These toads can bury themselves very effectively.
Photo courtesy Michael Benard/www.shutterstock.com

Searching further north

Back in Rhode Island, she tried spotlighting for spadefoots; it took her just 15 minutes to find one. The success led to a ten night survey in a pair of locations last summer that produced 42 sightings – a figure nearly double the total number of eastern spadefoot toad sightings recorded in the state over the previous seven decades!!

Devan-Song also learned that she wasn't the first to question the notion that the eastern spadefoot was so 'secretive' as to almost always avoid detection. As she points out, as far back as 1944, it had been suggested in scientific literature that the toad could be found at other times, apart from rain-induced migrations and breeding aggregations. In 1955, researchers had actually used spotlighting to detect huge numbers of eastern spadefoots in Florida; yet the technique subsequently and inexplicably fell into disuse.

A major misconception

"Confirmation bias perpetuated the fallacy of when the eastern spadefoot could be found," Devan-Song said. "No breeding events or migration occurred during our surveys and we detected thousands of toads in Virginia and dozens in Rhode Island. The majority of those were subadults, which is an age category mainly overlooked in the literature. Progress in learning about the toad, its ecology and its conservation has been greatly hindered by a misconception that persisted even when evidence to the contrary was presented."

The ease with which many toads could be found during breeding, combined with a lack of data on toads in upland habitats, helped fuel the confirmation bias in this case. "Everyone assumed they were underground most of the time so no one was really looking for them most of the time," Devan-Song explains. "Our research demonstrates that you can detect them year round, though they do remain quite rare in Rhode Island. But almost certainly not as rare as the scientific community thought!"

Further information

Anne Devan-Song, M. A. Walden, Haley A. Moniz, Justine M. Fox, Mary-Ruth Low, Emma Wilkinson, Scott W. Buchanan, Nancy E. Karraker. **Confirmation Bias Perpetuates Century-Old Ecological Misconception: Evidence Against 'Secretive' Behavior of Eastern Spadefoots**. *Journal of Herpetology*, 2021; 55 (2) DOI: 10.1670/20-044

Snake monitors

Ten years after one of the largest nuclear accidents in history spewed radioactive contamination over the landscape in Fukushima, Japan, a new study has shown that this contamination in the Fukushima Exclusion Zone can be measured very successfully through its resident snakes.

An abundant species in Japan, rat snakes travel short distances and can accumulate high levels of radionuclides in their bodies. According to the researchers, the snakes' limited movements and close contact with contaminated soil are key factors in their ability to reflect the varying levels of contamination within the zone.

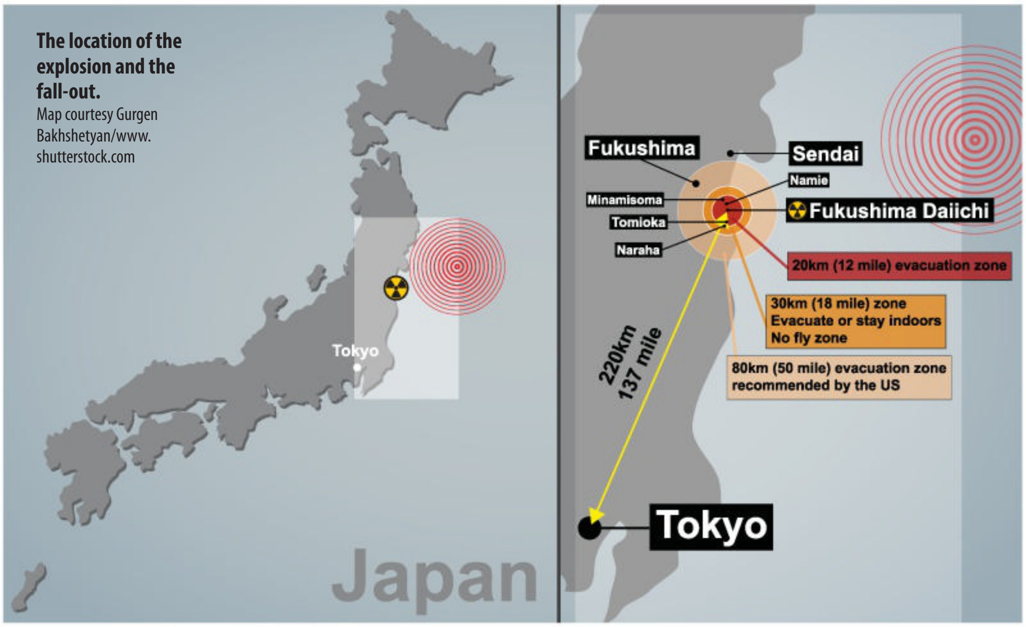
Hanna Gerke from the Savannah River Ecology Laboratory (SREL), part of the University of Georgia and the Warnell School of Forestry and Natural Resources, explains tracked snakes moved an average of just 65m (213ft) per day.

"Our results indicate that animal behaviour has a large impact on radiation exposure and contaminant accumulation," she says. "Studying how specific animals use contaminated landscapes helps increase our understanding of the environmental impacts of huge nuclear accidents such as Fukushima and Chernobyl."

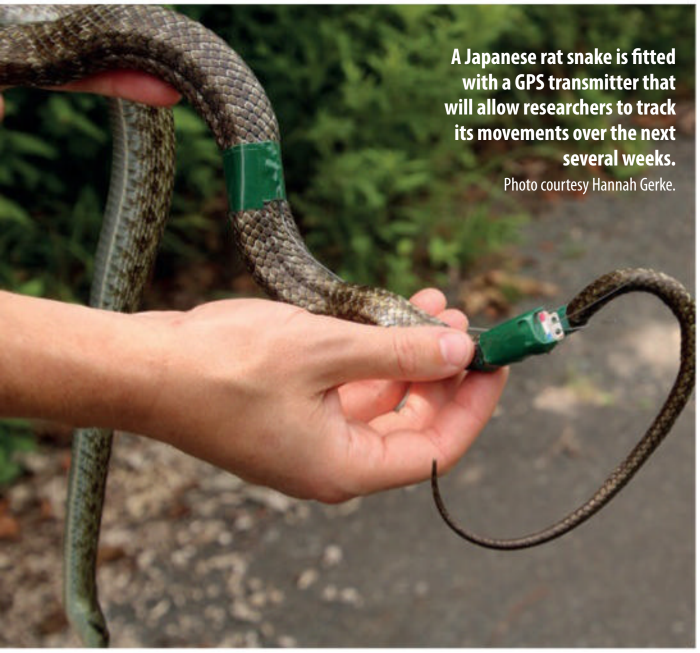
⮝ **A rat snake in the affected zone.**
Photo courtesy Hanna Gerke.

➤ **The site of the deadly explosion - the Fukushima nuclear plant.**
Photo courtesy Santiherllor/ www.shutterstock.com

⮟ **A Japanese rat snake crossing a rural road in the Fukushima Evacuation Zone in Japan.** Photo courtesy Hannah Gerke.



The location of the explosion and the fall-out. Map courtesy Gurgen Bakhshetyan/www.shutterstock.com



A Japanese rat snake is fitted with a GPS transmitter that will allow researchers to track its movements over the next several weeks. Photo courtesy Hannah Gerke.

The benefit of using snakes

Why are snakes a good indicator of radioactive contamination? James C. Beasley, Gerke's advisor during the study, reveals that snakes can serve as better indicators of local contamination in the zone than more mobile species like East Asian raccoon dogs, wild boar and song birds.

"Snakes are good indicators of environmental contamination because they spend a lot of time in and on soil," says Beasley, associate professor at SREL and Warnell. "They have small home ranges and are major predators in most ecosystems, and they're often relatively long-lived species."

The team identified 1718 locations of the snakes while tracking them for over a month in the Abukuma Highlands, approximately 24km (15ml) northwest of the Fukushima Daiichi Nuclear Power Plant. The paper's findings reinforce the team's previous research, which indicated the levels of radiocaesium in the snakes had a high correlation to the levels of radiation in the soil where the reptiles were caught.

Tracking the snakes

In order to determine where the snakes were spending their time and how far they were moving, the team tracked nine rat snakes using a combination of GPS transmitters and manual very-high frequency (VHF) tracking. Beasley said VHF transmitters allowed the team physically to locate a snake every few days to identify if it was underground or in arboreal habitat.

The researchers placed the transmitters on the rear back of the snakes. Tape was initially placed around the snakes. Then superglue was used to ensure the transmitters were secured to the tape. This allowed the transmitters to easily be removed from the animals at the conclusion of the study.

Working in the hilly, rugged terrain of abandoned villages and farms, the researchers located snakes in trees, grasslands and along roadside streams. Gerke said the snakes avoided the interior of conifer forests but were often found in deciduous forests, along forest edges and inside of abandoned buildings. More than half of the tracked snakes spent time in abandoned barns and sheds, which can help to shield them from contamination in the surrounding soil.

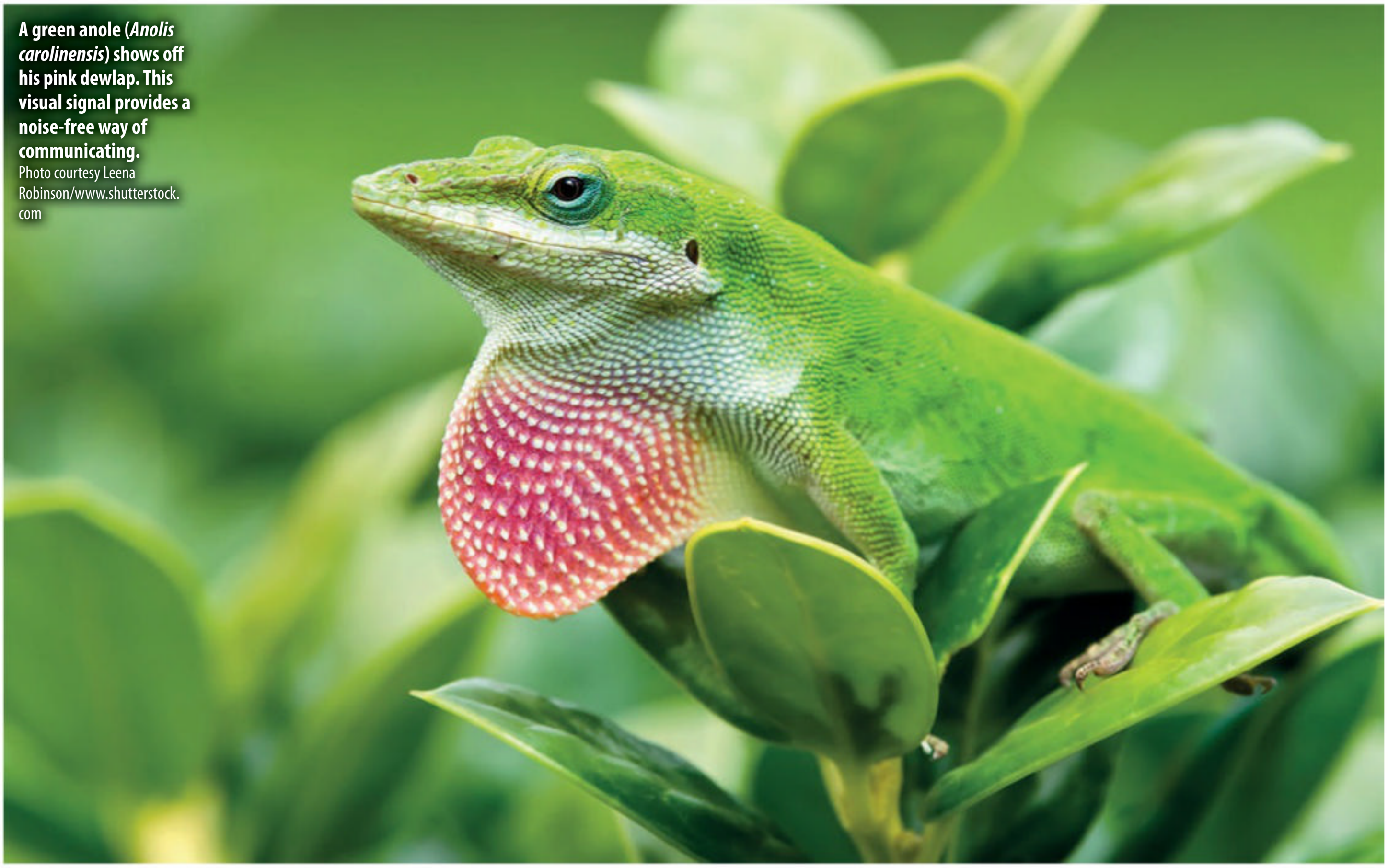
During winter months, their risk of exposure probably increases when they seek shelter underground, close to the more heavily contaminated soils. Future work to clarify the link between the micro-habitat use of species like snakes and their contaminant exposure, as well as the potential health risks to snakes and other wildlife as a result of increased radiation exposure, will be critical to understanding the effects of the Fukushima Daiichi accident on local wildlife populations.

⮝ **A Japanese rat snake conceals itself in a tree.** Photo courtesy Hannah Gerke.

Further information

Hannah C. Gerke, Thomas G. Hinton, James C. Beasley. **Movement Behavior and Habitat Selection of Rat Snakes (*Elaphe* spp.) in the Fukushima Exclusion Zone.** *Ichthyology & Herpetology*, 2021; 109 (2) DOI: 10.1643/h2019282

Driven to survive with similar strategies

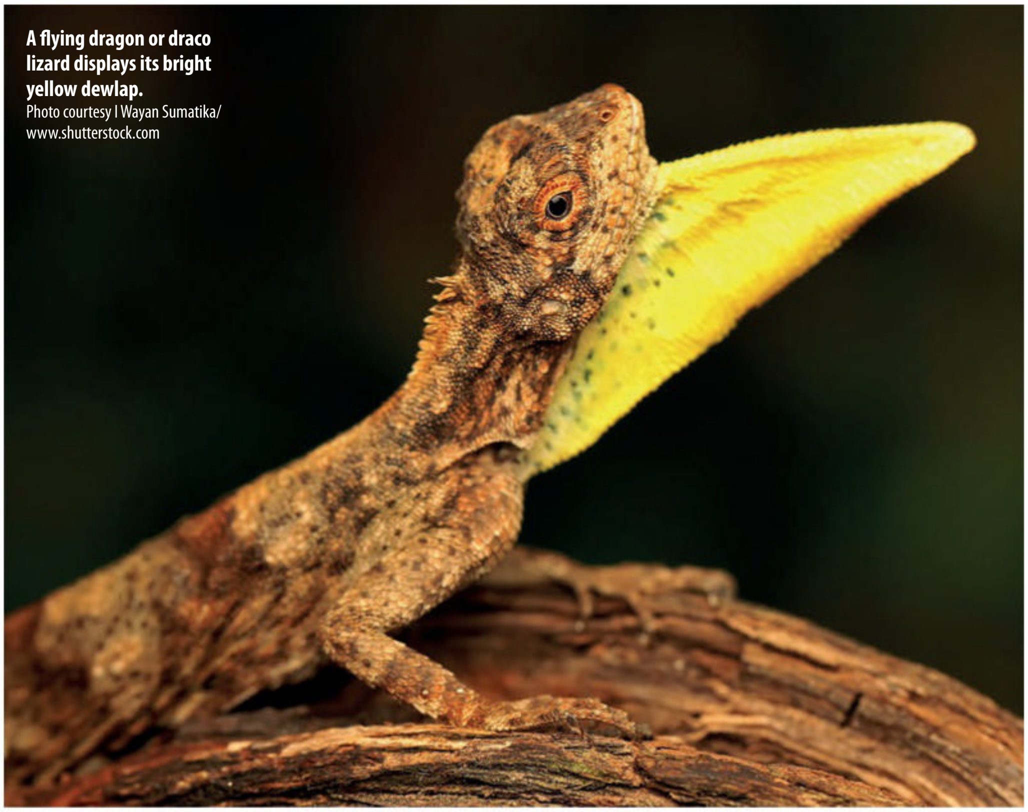


A green anole (*Anolis carolinensis*) shows off his pink dewlap. This visual signal provides a noise-free way of communicating.
Photo courtesy Leena Robinson/www.shutterstock.com

On the Caribbean island, a male anolis lizard is trying to capture the attention of a female in an area of rainforest. But the wind is blowing the vegetation around him, hampering his efforts to woo his intended mate, so he starts to perform an elaborate head bob. When that fails to achieve the required result, he does push-ups and extends and retracts his dewlap (the flap of skin under his throat).

Elsewhere in the world, about 20,000km (12,500ml) away, a male draco lizard in the Ulu Gombak mountains outside Kuala Lumpur in Malaysia has a similar problem – it's getting dark and the windblown vegetation is blurring his sight but he needs to show his male draco competitors that they are on his territory. So the draco lizard commences an elaborate head bob, followed by push-ups and extensions and retractions of his dewlap.

These two lizards aren't related, but they occupy the same type of habitat, and therefore face the same problems when it comes to communicating to a



A flying dragon or draco lizard displays its bright yellow dewlap.
Photo courtesy I Wayan Sumatika/www.shutterstock.com

⮝ **These two groups of lizards also have similar lifestyles, with both being largely arboreal. A Jamaican grey or stripe foot anole (*Anolis lineatopus*) is shown here.** Photo courtesy C. Hetzel/www.shutterstock.com

potential mate or enemy in visually 'noisy' environments. Remarkably, they have evolved the same strategy to cope with the same selection problems, according to Dr Terry Ord from the Evolution & Ecology Research Centre at the UNSW School of Biological, Earth and Environmental Sciences.

Similar for a reason

His research has revealed that this scenario of two unrelated lizards displaying similar behaviours shows that natural selection directs evolution towards the same common set of adaptive outcomes over and over again.

"The surprise is that lizards in both groups have evolved remarkably similar displays for communication, but they also tailor the production of those displays according to the prevailing conditions experienced at the time of display," Dr Ord says.

"That is, increasing the speed or the length of time they spend displaying the movements as the viewing conditions deteriorate. Really, there should be essentially innumerable ways that these lizards could have adapted their displays to remain effective, and there is strong evolutionary predictions that would lead us to expect this as well."

Dr Ord says what this study reveals is that natural selection driving similarities between different species. Formally, this is known as convergent evolution — the independent origin of similar adaptations. It seemed that these types of convergent, common adaptations are outcomes that would only really occur among species that are closely-related in some way," he explains.

"The reason for this is a bit complicated and it rests on the fact that adaptations build on characteristics that a species already possesses," Dr Ord explains. "So the longer species have evolved independently of each other, the less likely they would evolve the same adaptive solutions if they were exposed to the same change in the environment."

⮝ **Visual displays are common in the animal kingdom, being a feature particularly associated with birds of paradise for example, which live in rainforest areas full of sound.** Photo courtesy Dicky Asmoro/www.shutterstock.com

Overcoming problems

But this study highlights what many evolutionary ecologists have argued - that natural selection is an extremely powerful process that can override the "baggage" of past history to produce the same adaptations. "So if arm-waving is the most effective solution to some change in the environment, then natural selection would ultimately lead to its evolution rather than a more subtle (less effective) modification to an existing vocal call," he explains.

"Evolutionary biologists are excited about convergent evolution because it gives us multiple examples of the same adaptation evolving time and time again in very different animals. It tells us what the challenges are faced by these animals in their landscape and how they have solved it in terms of evolutionary adaptation."

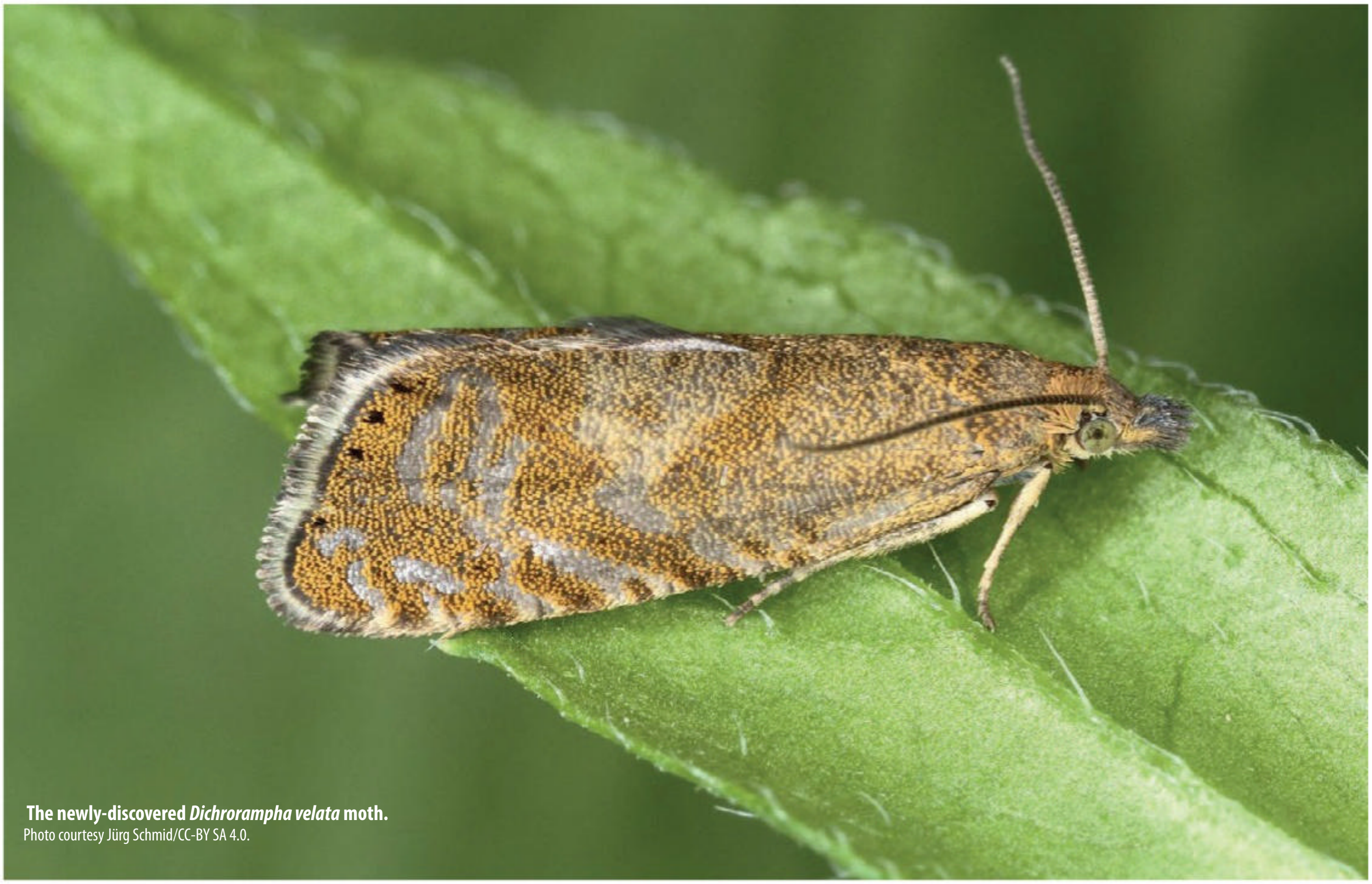
The study documents this independent evolution of common communication strategies amongst groups that have evolved separately from each other for hundreds of millions of years. Dr Ord says the striking similarities in communication strategies for maintaining an effective communication system in noisy conditions have evolved in various forms in many insects, fish, frogs, birds and mammals.

"For example, increasing the volume of calls when there's lots of acoustic background noise, or extending the length of those calls or even vibrational signals by spiders and such," he adds. "The fact that many other different groups of animals have also evolved these same adaptive strategies is even more extraordinary."

Further information

Terry J. Ord, Danielle A. Klomp, Thomas C. Summers, Arvin Diesmos, Norhayati Ahmad, Indraneil Das. **Deep-time convergent evolution in animal communication presented by shared adaptations for coping with noise in lizards and other animals.** *Ecology Letters*, 2021; DOI: 10.1111/ele.13773

The amazing discovery of a new moth



The newly-discovered *Dichrorampha velata* moth.
Photo courtesy Jürg Schmid/CC-BY SA 4.0.

Butterflies and moths (order Lepidoptera) represent one of the most diverse animal groups. To date, scientists have found as many as 5,000 species from the Alps alone. Having been a place of intensive research interest for 250 years, it would be considered quite a sensation if a previously unknown species awaited discovery in a European mountain range these days. Amazingly however, this was the case when a Swiss-Austrian team of researchers recently described a new species of Alpine moth, and by so doing, finally solved a 180-year-old mystery.

Decades of research work

Initially, the team comprising Jürg Schmid, a full-time dentist, author and passionate butterfly and moth researcher from Switzerland, and Peter Huemer, head of the natural science collections of the Tyrolean State Museums in Innsbruck, Austria and author of more than 400 publications, needed a lot of patience.

Almost thirty years ago, during the

The alpine habitat of the new moth species - *Dichrorampha velata*.
Photo courtesy Jürg Schmid/CC-BY SA 4.0.

▲ **It is thought that the caterpillars may develop in the roots of yarrow (*Achillea millefolium*).**
Photo courtesy Sunbunny Studios/www,shutterstock.com

1990s, the two researchers independently discovered the same moth species. While they found there were similarities to a moth of the leaf-roller family Tortricidae named as *Dichrorampha montanana* which had been known to science since 1843, it was also clearly different.

The wing pattern and internal shape of the reproductive organs supported the theory that they were not the same. Moreover, both were found at the same time in the same places - a further indication that they were separate species. Extensive genetic investigations later confirmed this hypothesis, but the path of presenting this new species to science was far from over.

The hidden Alpine moth

When it comes to naming a new species, scientists first have to check that it hasn't already been named. This prevents the same species from having two different names, creating a source of confusion. Essentially, this means looking at descriptions of similar species and comparing the new one against them to prove it is indeed unknown to science. In the case of this new moth, there were six potentially applicable older names that had to be ruled out before it could be listed as a new discovery.

Intensive and time-consuming research involving original specimens in the natural history museums of Paris, Berlin, Frankfurt and London eventually led to the finding that all six ancient names actually referred to one and the same species - *Dichrorampha alpestrana*, which has been known since 1843 and had to be adopted as the valid older name for *Dichrorampha montanana* simply because it had originally been described a couple of months earlier. Similarly, all other available names proved to be actual examples of *Dichrorampha alpestrana*.

The species discovered by Schmid and Huemer, however, was different. It had not yet been named, and therefore could finally be described as new to science. The authors chose to name it *Dichrorampha velata* - with its species name being derived from the Latin for "veiled" or "hidden" highlighting the complicated story behind its eventual discovery.

▼ **Some of the research was carried out using the collection of moth specimens at the Natural History Museum in London.**
Photo courtesy elRoce/www.shutterstock.com

Lots of unanswered questions

The hidden Alpine moth is a striking species with a wingspan of up to 16mm (0.6in) and a characteristic olive-brown colour of the forewings with silvery lines. It belongs to a group of mainly diurnal (day-time) moths and is particularly common locally in colourful mountain flower meadows.

As it stands, we know that its distribution extends at least from Salzburg and Tyrol through southern Switzerland and the Jura Mountains to the French and Italian Alps, with isolated finds known from the Black Forest in Germany, although the researchers believe it might have a wider range in Central Europe.

The biology of the new species is currently completely unknown, but Huemer and Schmid speculate that its caterpillars may live in the rhizome (root) of yarrow or chrysanthemums like other species of the same genus. As with many other alpine moths however, there is a strong need for further research, so we can get a better understanding of this fascinating insect.

Further information

Schmid J, Huemer P (2021) **Unraveling a complex problem: Dichrorampha velata sp. nov., a new species from the Alps hitherto confounded with *D. alpestrana* ([Zeller], 1843) sp. rev. = *D. montanana* (Duponchel, 1843) syn. nov. (Lepidoptera, Tortricidae).** *Alpine Entomology* 5: 37-54. https://doi.org/10.3897/alpento.5.67498

Tourism may represent a danger to tortoises

Contact between people and Galápagos tortoises could prove detrimental fort the reptiles.
Photo courtesy KKulikov/www.shutterstock.com

The giant Galápagos tortoises, which live on these islands off the western coast of South America, and come in contact with human farming and tourism activities, or in urbanised zones, have more bacterial resistance to antibiotics than those that live in more isolated ecosystems, according to new research which the Universidad Complutense de Madrid participated in, together with the Charles Darwin Foundation (FCD), the Institute for Conservation Medicine of the Saint Louis Zoo (ICM), the Centre for Animal Health Research (INIA-CISA) and Universidad Europea de Madrid.

Ainoa Nieto, one of team members, explains the new information provided by the study: "Human activities are facilitating the dispersal of antibiotic resistance into the environment, which has already been observed in other parts of the world, but which has never been demonstrated previously on the Galápagos Islands."

Resistance to antibiotics is one of the major threats to public health on the planet. The World Health Organisation has estimated that by 2050, it could be leading to more deaths than cancer, diabetes or traffic accidents. The detection of these bacteria in the Galápagos archipelago for the first time turn them into environmental pollutants and the tortoises into potential "sentinels or bioindicators" of the health of ecosystems there.

Giant Galápagos tortoises migrating. Photo courtesy Juan Manuel García.

PCR to identify genes and bacteria

To carry out the study, samples were taken from 270 tortoises in 2018 and 2019 in two locations with different characteristics in the Galápagos Islands: the island of Santa Cruz, which has the largest human population, and the remote volcano of Alcedo on the island Isabela.

The analyses of resistance were carried out in the INIA-CISA laboratory in Madrid using a new methodology that allows the detection of resistance genes without the need to cultivate the bacteria, through PCR reactions in real time. This technique helps identify the genes and also the number of bacteria with resistant genes that are present in a sample. In total, 21 genes were analysed that codify resistance for eight of the antibiotic families most commonly used in human and animal medicine.

"We don't know the real implications that this discovery could have for the health of giant tortoises, but resistance is considered environmental pollution, and the fact that species as iconic as Galápagos tortoises are entering into contact with these resistant bacteria implies that the ecosystem in which they live is being contaminated," explains Casilda Rodríguez, a researcher at the Department of Pharmacology and Toxicology at UCM.

Finally, Ainoa Nieto recalls that antibiotics can be bought in the Galápagos without a medical prescription, for both human and veterinarian use. The authorities do not restrict their use, as happens in Spain or other countries in the world.

Further information

Ainoa Nieto-Claudin, Sharon L.Deem, Casilda Rodríguez, Santiago Cano, Nicolas Moity, Freddy Cabrera, Fernando Esperón (2021) **Antimicrobial resistance in Galapagos tortoises as an indicator of the growing human footprint.** *Environmental Pollution,* 284, Sept 2021, 117453, https://doi.org/10.1016/j.envpol.2021.117453

New Australian crocodile found

The new crocodilian is thought to have been a member of the tomistomine group, of which only one species - often called the false gharial (*Tomistoma schlegelii*) - is alive today.
Photo courtesy Edwin Butler/www.shutterstock.com

A new species of large prehistoric crocodile that roamed the waterways of south-east Queensland millions of years ago has been documented by researchers from the University of Queensland (UQ). Jorgo Ristevski, from UQ's School of Biological Sciences, led the team that named the species *Gunggamarandu maunala* after analysing a partial skull that had been unearthed from the area of the Darling Downs back in the 19th century. "As far as we know, this is one of the largest crocs that has ever inhabited Australia," he says.

How big was it?

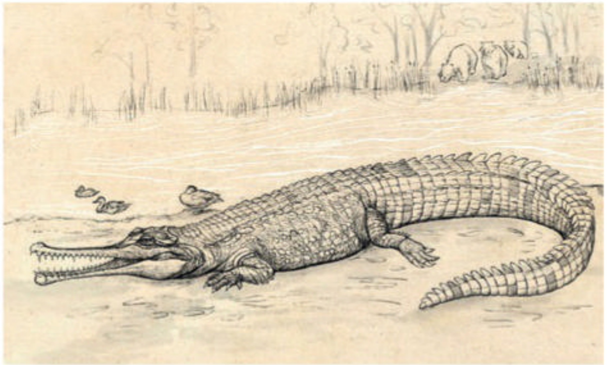
"At the moment it's difficult to estimate the exact overall size of gunggamarandu since all we have is the back of the skull – but it was massive. We estimate the skull would have been at least 80cm (31in) long, and based on comparisons with living crocs, this would indicate a total body length of around 7m (23ft).

"This suggests that size-wise, *Gunggamarandu maunala* was on par with the largest Indo-Pacific crocs (*Crocodylus porosus*) ever recorded. We also had the skull CT-scanned, and from that we were able to digitally reconstruct the brain cavity, which helped us unravel additional details about its anatomy. The exact age of the fossil is uncertain, but it's probably between 2-5 million years old."

A new range record

Gunggamarandu belonged to a group of crocodylians called tomistomines or 'false gharials'. "Today, there's only one living species of tomistomine, known as *Tomistoma schlegelii*, which is restricted to the Malay Peninsula and parts of Indonesia," Jorgo Ristevski explains.

"With the exception of Antarctica, Australia was the only other continent without fossil evidence of tomistomines. But now with the discovery of gunggamarandu, we can add Australia to the list of localities once inhabited by members of this group."



⌄ **A representation of *Gunggamarandu maunala*.**
Artwork courtesy Eleanor Pease.

A distinctive appearance

Despite its discovery, the fossil skull of *Gunggamarandu maunala* remained a scientific mystery for more than a century.

The specimen piqued the interest of then-young graduate student Dr Steve Salisbury in the 1990s, but a formal study was not done until Jorgo Ristevski began his examination.

"I knew it was unusual, and potentially very significant, but I didn't have the time to study it in any detail," Dr Salisbury admits.

"The name of the new species honours the First Nations peoples of the Darling Downs area, incorporating words from the languages of the Barunggam and Waka Waka nations. The genus name, *Gunggamarandu*, means 'river boss', while the species epithet, *maunala*, means 'hole head'. This description refers to the distinctive large, hole-like openings located on top of the reptile's skull that served as a place for muscle attachments."

⌃ **The remains of *Gunggamarandu maunala* were found in the region of Darling Downs in Queensland.**
Photo courtesy Adam Hanley/www.shutterstock.com

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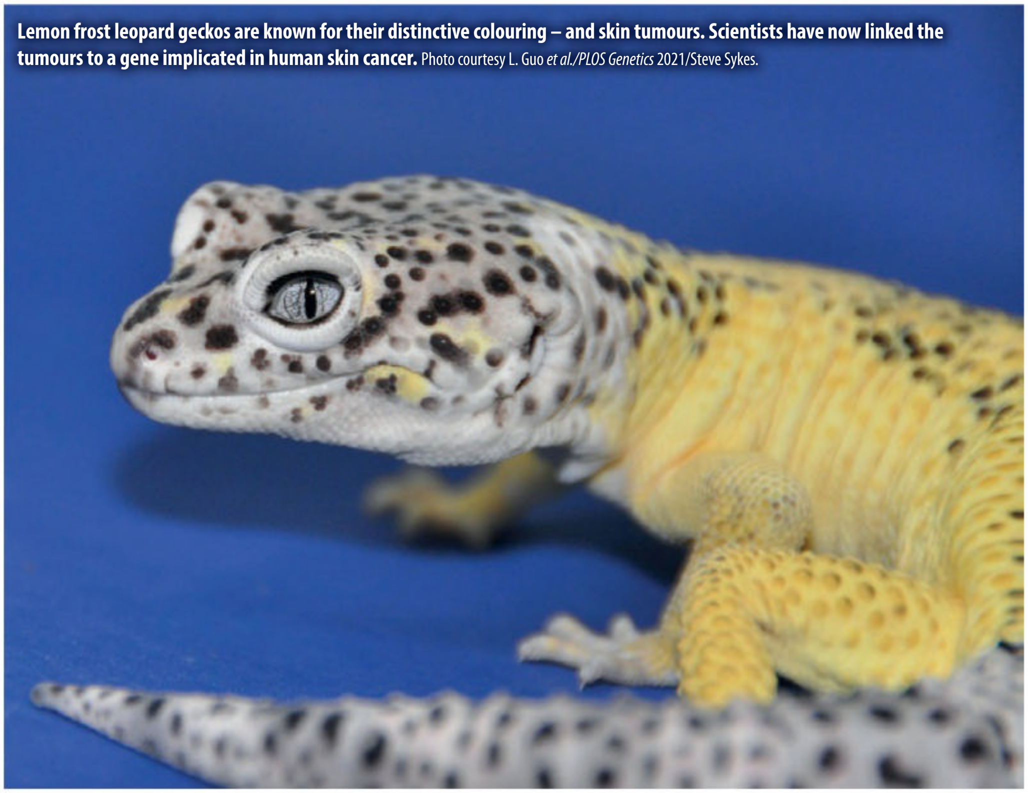
Alejandro Serrano–Martínez, Fabien Knoll, Iván Narváez, Stephan Lautenschlager, Francisco Ortega. **Neuroanatomical and neurosensorial analysis of the Late Cretaceous basal eusuchian *Agaresuchus fontisensis* (Cuenca, Spain).** *Papers in Palaeontology*, 2020; 7 (1): 641 DOI: 10.1002/spp2.1296

Investigating leopard gecko colours

The leopard gecko's name was Mr. Frosty, and he was hard to miss in amongst the other leopard geckos, as a result of his distinctive patterning. Lemon-yellow areas predominated over his body, with contrasting whitish areas evident amid the speckles on his head and tail. "It's a really striking colour pattern," says Howard Hughes Medical Institute Investigator Leonid Kruglyak, a geneticist at the University of California, Los Angeles (UCLA).

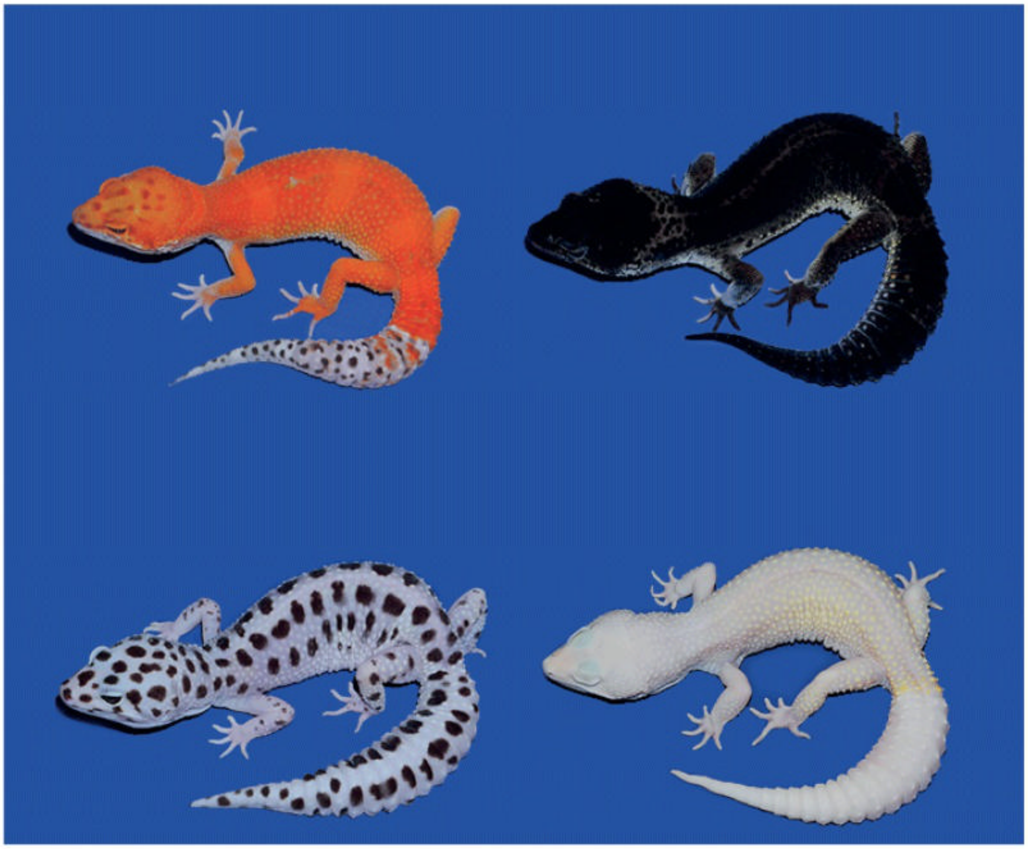
A Californian reptile store began breeding with Mr. Frosty in 2016 and produced a colony of this particular colour variety, with the morph becoming known as the lemon frost. With their bold bands and snazzy spots, these attractive and unusual geckos could fetch upwards of £1500/ US $2,000.



Lemon frost leopard geckos are known for their distinctive colouring – and skin tumours. Scientists have now linked the tumours to a gene implicated in human skin cancer. Photo courtesy L. Guo *et al./PLOS Genetics* 2021/Steve Sykes.

A major issue

But the gaudy geckos have a problem. Roughly 80 percent develop bulbous white skin tumours within the first five years of life. In some individuals, these tumours can become massive, making it difficult for the animals to move and potentially causing infection if these swellings rupture. Kruglyak and his colleagues suspected a genetic cause – possibly a single mutation in a single gene. "It seemed likely that the same thing that was giving the geckos such unusual colouration was also causing the tumours," he says.



⮝ **The leopard gecko (*Eublepharis macularius*) is now seen in a wide variety of colours and patterns, including (clockwise from top left) sunburst tangerine, black night, white knight and gem snow, as shown here.** Photo collage courtesy L. Guo *et al./PLOS Genetics* 2021/Steve Sykes

Now, using a variety of genetic analyses, his team has traced the tumours and colouring to a gene implicated in skin cutaneous melanoma, a deadly cancer in humans.

"To identify the genetic basis of this trait in reptiles is really marvellous," says Douglas Menke, a developmental geneticist at the University of Georgia who was not involved with the work. As Menke explains, genetic studies in reptiles are uncommon, and those with biomedical relevance even rarer. Like mice and zebrafish studied in the laboratory, the leopard gecko could one day therefore serve as model for scientists researching melanoma.

A colourful collaboration

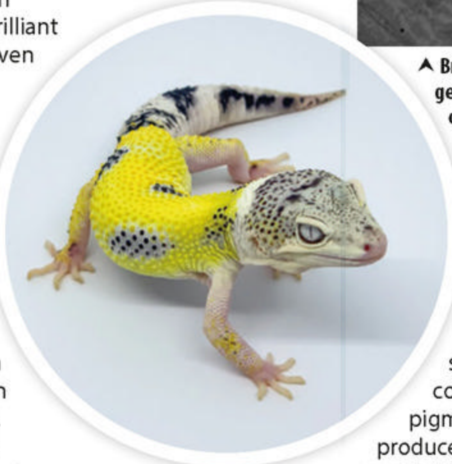
When Longhua Guo first joined Kruglyak's lab in 2017, he was looking for an interesting project. Inspiration struck when he discovered an article online about leopard geckos. "The images immediately jumped out at me," Guo says. "These lizards have so many fascinating colours and patterns."

Over recent years of course, leopard geckos have been bred in an ever-increasing variety of brilliant shades, which have been given names such as sunburst tangerine, black night and granite snow, but scientists didn't know much about the genetics behind the variants. "We have a very limited understanding of how the animals display this amazing variety of colours," admits Kruglyak. In fact, relatively little is known about reptile genetics at all.

Lizards and snakes aren't established laboratory animals like mice, and scientists haven't developed extensive tools for studying them. The leopard gecko genome, for example, hasn't been carefully spelled out, and no one has pinpointed which genes lie on which chromosomes.

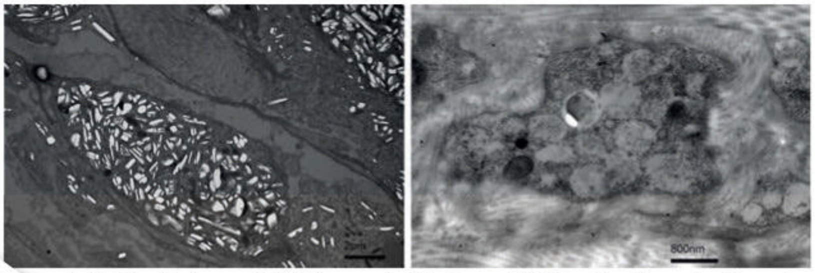
"Leonid was so excited and started doing calculations on animal numbers and laying out a mapping strategy when we first talked about investigating this area," Guo recalls. But if he and Kruglyak wanted to figure out which genes were behind which colours, they first needed gecko DNA to begin a study.

Guo pitched the idea to Steve Sykes, a reptile breeder in California. Sykes had hundreds of geckos, meticulous breeding records, and, it turned out, a passion for science. "It was a very lucky moment in my life," Guo remembers. Sykes agreed to collaborate with the scientists and introduced them to Mr. Frosty and his colourful cousins.



▲ **The lemon frost is a striking variant, but the team identified a a serious genetic weakness in its make-up.** Photo courtesy worenpets/ www.shutterstock.com

▼ **A blizzard leopard gecko.** Photo courtesy Destinys Agent/www.shutterstock/com



▲ **Bright, reflective crystals (left) appear in iridophores within the skin of lemon frost leopard geckos. In the skin of normal geckos (right), iridophores are less dense and have fewer crystals.** Photo courtesy L. Guo et al./PLOS Genetics 2021

Gene hunters

The dazzling colours of many animals, including tropical fish, chameleons and leopard geckos, come from cells called iridophores. Unlike human skin cells, which get their colour from the chemical pigment melanin, iridophores produce colours via crystals. These crystals' shape and structure affect how they bend and reflect light, producing a rainbow of possible colours.

In leopard geckos, the arrangement of the crystals gives rise to a white appearance.

Guo collected DNA from 500 of these lizards and then read the genetic "letters" of the animals' genomes. The team was hunting for DNA regions that they could link to certain colour varieties – in particular, the genetic signposts that occurred only in lemon frost animals.

Kruglyak's laboratory isn't a reptile lab, and his team had never before studied leopard geckos. But his research does focus on the genetic basis of a variety of traits in different organisms. He's examined yeast strains with unusual metabolism and roundworms that are resistant to certain drugs. The gecko project offered a new twist on Kruglyak's team's specialty – mapping a particular trait to a specific region in the genetic code or genome.

The researchers mapped the lemon frost trait to a region that contained a single gene, called SPINT1. This gene had already been linked to cancer in humans and other animals. Without a functioning SPINT1 gene, both mice and zebrafish, for example, develop tumours. Scientists have also implicated the gene in human skin, causing cutaneous melanoma.

Given the gene's known role in cancer, it's a clear candidate for what is causing tumours in lemon frost geckos, according to Kruglyak. It's possible that errors within the gene ramp up production of white skin cells and the light-reflecting crystals within them, giving the geckos their characteristic bright colouring – and their tumours.

Further investigations

Following on from this initial study, Guo wants to pursue the genetic basis of even more lizard colours, including two varieties called blizzard and patternless, which lack all colours and patterns. He and Kruglyak don't know if the work will uncover other findings potentially relevant to human health. That's the thing with curiosity-driven research, according to Kruglyak. Studying unusual phenomena out of pure curiosity can take scientists in surprising directions, and end up revealing new insights into important molecular pathways.

Further reading

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LIFE-SAVING SNAKE VENOM

Many people suffer from ophidiophobia, meaning a fear of snakes, and scientist Kibret Mequanint is amongst them. Even so, the bioengineering professor, based at Canada's Western University, has overcome this feeling to work with one of the most deadly snakes in the world. As a result, Kibret and a team of international collaborators have found a novel use for its venom: a body tissue 'super glue' that can stop life-threatening bleeding in seconds.

➤ The description of 'lance head' refers to the triangular shape of the head of this snake.
Photo courtesy reptiles4all/ www.shutterstock.com

◀ Professor Kibret Mequanint who has led the way in this new research.
Photo courtesy Kibret Mequanint.

Over the past 20 years, Mequanint has developed a number of medical devices and therapeutic technologies derived from biomaterials – some of which are either licensed to medical companies or are in the advanced stages of preclinical testing. His latest collaborative research discovery is based on a blood-clotting enzyme called reptilase or batroxobin, found in the venom of the lancehead snake (*Bothrops atrox*), a member of the fer-de-lance group, which ranks amongst the most venomous snakes found in the Americas.

How it can be used

Taking advantage of the clotting property found in the venom, Mequanint and the international research team designed a body tissue adhesive that incorporates the special enzyme in a modified gelatin, which in turn can be packaged into a small tube for easy, and potentially life-saving, application.

"During trauma, injury and emergency bleeding, this 'super glue' can be applied by simply squeezing the tube and shining a visible light, such as a laser pointer, over it for few seconds. Even a smartphone flashlight will do the job," explains Mequanint.

Compared with clinical fibrin glue, considered the best option currently available for clinical and field surgeons, the new tissue sealant has ten times the adhesive strength to resist detachment or washout due to bleeding. The blood clotting time is also much shorter, cutting it in half from 90 seconds for fibrin glue to 45 seconds for the new snake venom 'super glue.'

Visitors to snake collections, as here at Thailand's Siam Serpentarium, may be in awe of the deadly species resident there, little suspecting that such reptiles can be life-savers.
Photo courtesy chanon83/www.shutterstock.com

Snake venoms still hold many mysteries.
Photo courtesy Joe McDonald/www.shutterstock.com

The applications

This new biotechnology translates to less blood loss and more life-saving. The super-sealant was tested in models for deep skin cuts, ruptured aortae, and severely injured livers – all considered as major bleeding situations.

"We envision that this tissue 'super glue' will be used in saving lives on the battlefield, or following accidental traumas like car crashes," says Mequanint. "The applicator has been designed so it easily fits in first aid kits. In addition, the new snake venom 'super glue' can also be used for suture-free, surgical wound closures."

Further information

Yicheng Guo, Ying Wang, Xiaohong Zhao, Xue Li, Quan Wang, Wen Zhong, Kibret Mequanint, Rixing Zhan, Malcolm Xing, Gaoxing Luo. **Snake extract–laden hemostatic bioadhesive gel cross-linked by visible light.** *Science Advances,* 2021; 7 (29): eabf9635 DOI: 10.1126/sciadv.abf9635

Reptiles suffer a mass extinction

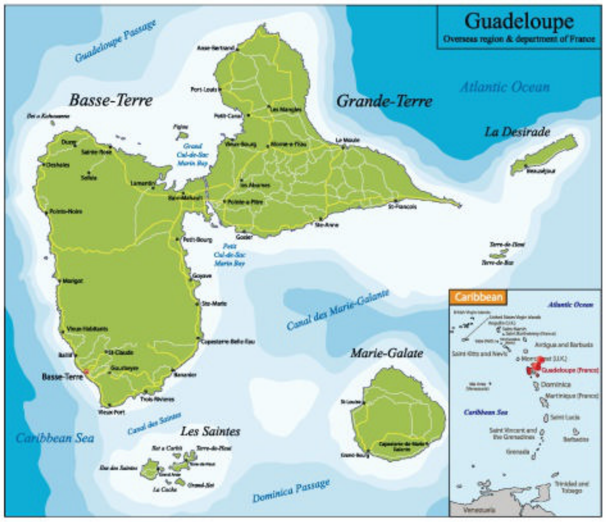
⮝ Guadeloupe has a long history of European colonisation, and represents a group of islands - some of which are too small for human habitation. Photo courtesy YaromirM/ www.shutterstock.com

A new study led by Dr. Corentin Bochaton and Professor Nicole Boivin of the Max Planck Institute (MPI) for the Science of Human History in Jena, Germany, reveals a much higher level of extinctions among the snakes and lizards of Guadeloupe following European colonisation than had been previously believed.

Partnering with colleagues from five other institutions, the team studied an extraordinary 43,000 individual bone remains from fossil and archaeological studies on six islands, ultimately revealing that a staggering 50% to 70% of Guadeloupe's squamate (snake and lizard) species went extinct after the arrival of European colonialists.

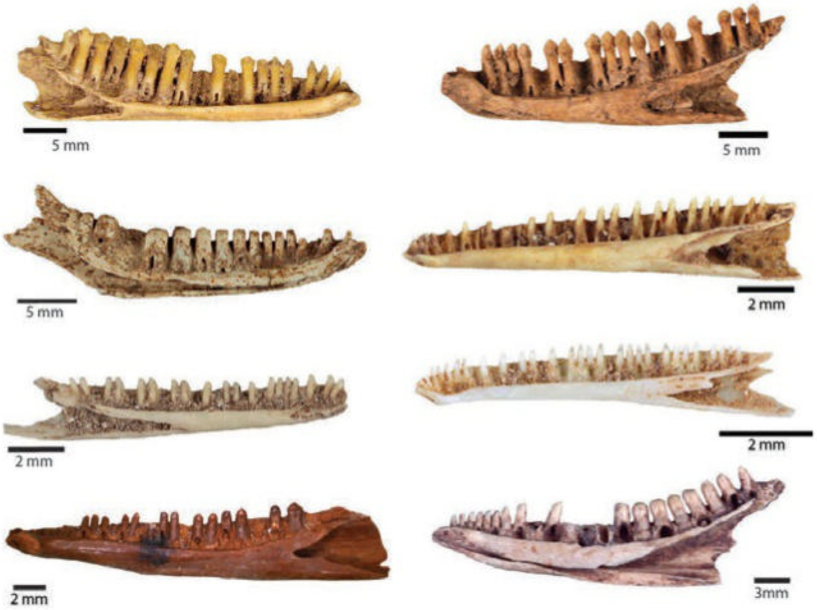
Living in harmony

This enormous loss of biodiversity stands in stark contrast to the pre-colonial record, which shows that indigenous human populations co-existed with the islands' snakes and lizards for thousands of years. In fact, the biodiversity of Guadeloupe's reptiles actually increased during the long history of indigenous habitation, with no evident extinctions and the introduction of two new lizard species.



Guadeloupe
Overseas region & department of France
Guadeloupe Passage
Basse-Terre
Grande-Terre
Atlantic Ocean
La Desirade
Grand Cul-de-Sac Marin Bay
Petit Cul-de-Sac Marin Bay
Canal des Marie-Galante
Marie-Galate
Caribbean Sea
Canal des Saintes
Les Saintes
Dominica Passage
Basse-Terre
Caribbean
Atlantic Ocean
Antigua and Barbuda
Saint Kitts and Nevis
Guadeloupe (France)
Dominica
Martinique (France)
Caribbean Sea
Saint Lucia
Saint Vincent and the Grenadines
Barbados
Grenada
Trinidad and Tobago
Venezuela

⮟ The islands of Guadeloupe and their position in the Caribbean. Photo courtesy Volvina/www. shutterstock.com



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⮝ Mandibles of various lizard species identified in the fossil material from the islands comprising Guadeloupe. Photo © Bochaton et al., 2021. *Science Advances.*

"The long-term data from Guadeloupe are concerning," admits Professor Boivin, Director of the Department of Archaeology at the MPI in Jena. "Snakes and lizards persisted through a broad range of climatic, environmental and human-induced changes on Guadeloupe over thousands of years. They do not appear to be sensitive animals. Yet in the last few hundred years, their diversity has plummeted."

Archaeology and conservation

This new research underscores the potential of archaeological and fossil evidence to provide information that is highly relevant in the modern world. "Our research strongly advocates for the study of past biodiversity to address current conservation issues and for research into less charismatic animals like reptiles, which are an essential part of tropical ecosystems," says Bochaton.

The use of fossil data from

Guadeloupe allowed the team to closely examine the dynamics of the extinctions, revealing links between species' body size, habitat preference, and risk of extinction. Medium-sized, terrestrial species sustained the greatest losses, with recently-introduced mammalian predators such as mongooses and cats being the primary causes of Guadeloupe's reptile extinctions.

⮝ An anolis lizard (*Anolis ferreus*) from Marie-Galante Island in Guadeloupe. Photo courtesy © Corentin Bochaton.

Agricultural impacts too

The extinction trends also highlight the impacts of a shift to intensive colonial agriculture. The destruction and fragmentation of habitats, combined with the degradation of soil and decimation of invertebrate populations, placed enormous pressure on Guadeloupe's snake and lizard species.

⮝ Farming - and the control of invertebrates - also appears to have had a very harmful effect on the numbers of snakes and lizards on Guadeloupe. Bananas (as see here) and sugar cane have both become major crops. Photo courtesy PV971/www.shutterstock.com

"In recent years, recognition of early human impacts has led to a kind of acceptance of humans as this inherently destructive species," says Professor Boivin. "Yet the Guadeloupe data clearly show that indigenous lifestyles of the native people were supportive of snake and lizard biodiversity, in contrast to those of European ones. This provides us with important information for future management and sustainability initiatives, and calls into question some of the ways conservationists deal with indigenous communities globally."

The researchers hope that more of such studies will help managers and conservationists create realistic, data-driven strategies for mediating societal impacts on ecosystems. "Archaeology budgets all around the world are under threat," observes Professor Boivin. "But without our past, we move forward blindly. Study of the past, present and future must be intertwined."

⮟ The mongoose (*Herpestes javanicus*) was introduced by colonists to the islands of Guadeloupe in the 1880s as a method of controlling rats. Photo © Omkar Vinchu from Pexels.

Further information

Corentin Bochaton, Emmanuel Paradis, Salvador Bailon, Sandrine Grouard, Ivan Ineich, Arnaud Lenoble, Olivier Lorvelec, Anne Tresset, Nicole Boivin. **Large-scale reptile extinctions following European colonization of the Guadeloupe Islands.** *Science Advances*, 2021; 7 (21): eabg2111 DOI: 10.1126/sciadv.abg2111

Deadly spider venom to save heart attack victims?

The Fraser Island (K’gari) funnel web spider.
Photo courtesy UQ.

A potentially life-saving treatment for heart attack victims has been discovered from a very unlikely source – the venom of one of the world’s deadliest spiders. It is a funnel web spider – one of approximately 40 species found in Australia – which has evolved in isolation on an island.

An amazing discovery

A drug candidate developed from a molecule found in the venom of the Fraser Island (K’gari) funnel web spider (*Hadronyche infensa*) can prevent damage caused by a heart attack and extend the life of donor hearts used for organ transplants.

The discovery was made by a team led by Dr Nathan Palpant and Professor Glenn King from the University of Queensland (UQ) in Australia and Professor Peter Macdonald, based at the Victor Chang Cardiac Research Institute.

Dr Palpant, who works at UQ’s Institute for Molecular Bioscience (IMB), said the drug candidate acted by stopping a ‘death signal’ sent from the heart in the wake of an attack.

“After a heart attack, blood flow to the heart is reduced, resulting in a lack of oxygen to heart muscle,” Dr Palpant said. “The lack of oxygen causes the cell environment to become acidic, which sends a message for heart cells to die. Despite decades of research, no one has been able to develop a drug that stops this death signal in heart cells, which is one of the reasons why heart disease continues to be the leading cause of death in the world.”

⮟ Fraser Island lies off the east coast of Australia, north of Queensland’s state capital, Brisbane.
Photo courtesy SevenMaps/www.shutterstock.com

Gladstone
Bundaberg
Fraser Island
Maryborough
Maroochydore
Brisbane
Gold Coast

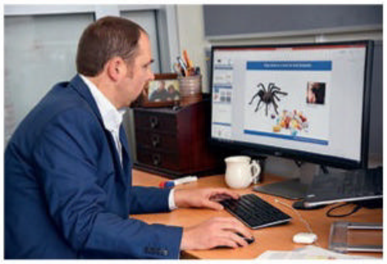
Dr Palpant tested the drug candidate, a protein called Hi1a, using beating human heart cells exposed to heart attack stresses to see if the drug improved their survival. “The Hi1a protein from spider venom blocks acid-sensing ion channels in the heart, so the death message is blocked, cell death is reduced, and we see improved heart cell survival,” he explains.

⮝ Fraser Island is the largest sand island in the world, making it relatively easy for the spiders to burrow into the ground.
Photo courtesy Guillem Lopez Borras/www.shutterstock.com

A unique treatment?

There are currently no drugs in clinical use that prevent the damage caused by heart attacks, so this is a very significant breakthrough - all thanks to an arachnid! “This will not only help the hundreds of thousands of people who have a heart attack every year around the world, it could also increase the number and quality of donor hearts, which will give hope to those waiting on the transplant list,” he explains.

“The survival of heart cells is vital in heart transplants — treating hearts with Hi1a and reducing cell death will increase how far the heart can be transported and improve the likelihood of a successful transplant. Usually, if the donor heart has stopped beating for more than 30 minutes before retrieval, the heart can’t be used — even if we can buy an extra 10 minutes, that could make the difference between someone having a heart and someone missing out. For people who are literally on death’s door, this could be life-changing.”



⮝ Dr Nathan Palpant at work.
Photo courtesy Dr Nathan Palpant/UQ.

Benefits stroke victims too

The discovery builds on earlier work by

Funnel-web spiders live underground in burrows. Photo courtesy allistermac/www.shutterstock.com

Professor King, who identified a small protein in the venom of the Fraser Island (K'gari) funnel-web spider that was shown to markedly improve recovery from stroke.

"We discovered that this small protein, Hi1a, amazingly reduces damage to the brain even when it is given up to eight hours after the onset of a stroke," Professor King explains.

"It made sense also to test Hi1a on heart cells, because like the brain, the heart is one of the most sensitive organs in the body to the loss of blood flow and lack of oxygen.

"For heart attack victims, our vision for the future is that Hi1a could be administered by first responders in the ambulance, which would really change the health outcomes of heart disease. This is particularly important in rural and remote parts of Australia where patients and treatment hospitals can be long distances apart – at a time when every second counts.

"Also, this could help to assist the transfer of donor hearts for cardiac transplantation – allowing these donor hearts to be transported over longer distances and therefore increasing the network of available donors and recipients."

➤ **Team member Dr Meredith Redd in the laboratory.** Photo courtesy Dr Meredith Redd/UQ.

The protein has been tested in human heart cells, and the team is aiming for human clinical trials for both stroke and heart disease within 2-3 years.

⮝ **The funnel web marking the entrance to the spider's burrow.** Photo courtesy Koelen/www.shutterstock.com

Further information

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How a gecko copes after losing its tail

The study focused on the western banded gecko (*Coleonyx variegatus*).
Photo courtesy Creeping Things/ www.shutterstock.com

Geckos and some other lizards can distract predators by quickly shedding their tail and escaping from them as a result. The tail vertebrae are perforated, making it easier to disconnect them without any formation of scar tissue or loss of blood. Though this ability can keep lizards from being eaten, the manoeuvre is performed at a cost.

What happens when hunting

"Other studies have documented the negative effects of tail loss on the abilities of lizards to run, jump, mate, and reproduce," says UCR biologist Marina Vollin. "However, few have examined their ability to capture food when they lose their tails, which is critical for regenerating the tail and for their overall survival."

To help fill this gap in understanding, Vollin and Tim Higham, an associate professor in UCR's

The western banded gecko, as seen in San Bernardino County, California.
Photo courtesy Connor Long.

⮝ **A day gecko in Madagascar that has lost its tail may be in a better position to survive than a western banded gecko, as it frequently feeds on static items such as nectar and ripe fruit.** Photo courtesy sturmphotography/www.shutterstock.com

⮝ **The shed tail of a western banded gecko, discovered in the Mojave desert. These geckos, native to the southwestern USA and Mexico, are one of the few reptiles that help to control scorpion populations.**
Photo courtesy Viktor Loki/www.shutterstock.com

Department of Evolution, Ecology, and Organismal Biology, observed intact and newly tailless geckos on the hunt. They found that geckos successfully captured crickets about 77% of the time both before and after losing tails — a surprising retention of accuracy since tails appear to help stabilise the body positions of the gecko during and after a strike. "The geckos were nevertheless much slower without tails, and their attack strikes much more awkward," Vollin observes.

Impacts in the wild

In this study, the geckos were observed hunting crickets in artificial enclosures. Vollin and Higham are planning future studies in which they hope to observe geckos hunting in the wild and feeding on other small insects.

"It is very possible that geckos suffer a loss in feeding performance and success following autotomy in nature given the complexity of the habitat and more room for the prey to escape," Higham explains.

They will also study whether geckos are able to fully regain their agility once their tails have regenerated, which can take up to a month. "It's important to get a sense of how they operate in nature, where additional elements could affect whether they have more difficulty capturing prey," adds Vollin.

Understanding how lizards like the western banded gecko are able to survive carries a significance beyond the lizards themselves. Though they eat a variety of small insects, they also serve as a key food source for birds, snakes and predatory mammals.

Further information

Marina F Vollin, Timothy E Higham. **Tail Autotomy Alters Prey Capture Performance and Kinematics, but not Success, in Banded Geckos.** *Integrative and Comparative Biology*, 2021; DOI: 10.1093/icb/icab076

GOPHER TORTOISE STUDIES

The gopher tortoise (*Gopherus polyphemus*) is declining because of habitat loss and fragmentation, human interaction (including collisions with vehicles), predation by domestic animals, and disease. These long-lived reptiles, which are found throughout Florida, are known to be affected by various diseases, particularly those of the upper respiratory tract. A number of disease-causing organisms such as *Mycoplasma* spp., herpesvirus and ranavirus are documented as having adverse impacts on this area of the body.

Chronic, long-standing disease resulting from these pathogens can lead to reduced reproduction, abnormal growth and development, increased susceptibility to secondary infections and, in some cases, a shorter lifespan. Up until now, however, little has been known about the prevalence of these microorganisms in wild tortoises. This lack of knowledge creates a dilemma for wildlife biologists, conservationists and public policy makers seeking to uphold and improve protections for this threatened species.

In the light of such a shortage of information, researchers from Florida Atlantic University's Harbor Branch Oceanographic Institute and the Harriet L. Wilkes Honors College, in collaboration with Loggerhead Marinelife Center and the University of Florida College of Veterinary Medicine, set out to conduct a comprehensive health assessment of previously unstudied gopher tortoise populations at two sites in southeastern Florida.

Researchers assessed the health of gopher tortoises, including these two hatchlings, at two sites in southeastern Florida. Photo courtesy Bethany Augliere.

Health status

Results of the study showed that overall, 42.9 percent of all tortoises tested had circulating antibodies to *Mycoplasma agassizii*, an infectious bacterium that is a common cause of upper respiratory tract disease. Researchers detected antibodies to *M. agassizii* in 29 percent of tortoises at one of the sites and 70 percent at the other, suggesting that at least one of these tortoise aggregations may be experiencing an outbreak of mycoplasmosis.

In contrast however, none of the tortoises tested positive for ranavirus or herpesvirus using the polymerase chain reaction (PCR) method. This is significant, given that these viruses are thought to be emerging pathogens in the case of other tortoise and turtle species.

For the study, researchers collected samples of blood and nasal, oral, and cloacal swabs from 91 tortoises (48 adults, 35 juveniles and eight hatchlings) found at FAU Harbor Branch in Fort Pierce, and Loggerhead Park in Juno Beach. The samples were analysed for haematology, plasma protein electrophoretic profiles, and infectious disease testing including *Mycoplasma* spp. serology and PCR assays for ranavirus, herpesvirus and *Anaplasma* spp., a tick-borne bacterium of medical importance.

Long-standing issues

At both study sites, it emerged that adult tortoises were significantly more likely to have clinical signs of upper respiratory tract disease than juveniles. There was also a significant relationship between the size of the tortoise and

▼ The incidence of respiratory infections was lower in young gopher tortoises. Photo courtesy Wildpix 645/ www.shutterstock.com

the antibody test results for *M. agassizii*, with bigger animals being more likely to have antibodies.

Physical examination revealed that nearly 20 percent of the tortoises had clinical signs consistent with upper respiratory tract disease, including nasal discharge, asymmetrical nares (a difference in the size of the nostrils), wheezing, eyelid/conjunctival swelling, and ocular discharge. In addition, just over 13 percent of tortoises were seen to have some other form of physical abnormality, such as limb, eye and shell abnormalities or extra scutes on the tortoise's shell.

"The full effect of chronic disease on a long-lived species such as the gopher tortoise may take months to years to manifest in a population," explains Annie Page-Karjian, a clinical veterinarian and an assistant research professor.

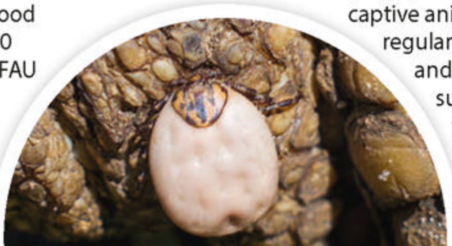
"Because the gopher tortoise is one of the most commonly translocated species in North America, being moved from one location to another, it is important to understand pathogen distributions within their populations and to monitor them using standardised techniques, so that any changes associated with health problems may be detected over time. This should then protect other individuals."

⮝ Moving these tortoises from one area to another can easily spread disease to a new population. Photo courtesy Barb Elkin/www.shutterstock.com

The parasitic relationship

Researchers also found that adult tortoises were significantly more likely than juvenile tortoises to have ticks on their bodies, as well as haemogregarine parasites in their red blood cells. The presence of ticks predisposes tortoises to haemogregarine parasites.

Ticks were found on 59 percent of the tortoises checked and blood parasites were identified in 30 percent of those sampled at FAU Harbor Branch. In contrast, only a single tick was found, and no haemoparasites were identified in tortoises at Loggerhead Park.



A gopher tortoise tick, which has anchored itself to the skin of the tortoise using its mouthparts, before feeding on the reptile's blood and swelling in size. Photo courtesy Chase D'animulls/www.shutterstock.com

These findings are noteworthy because haemogregarines in tortoises are thought to be transmitted by ticks.

"Free-ranging animals typically have higher internal and external parasite burdens and are likely to be exposed to pathogens more frequently than captive animals, which often are regularly treated with parasiticides and also receive supportive care such as anti-microbials when they are sick," adds Page-Karjian.

"Long-term studies of these and other gopher tortoise populations will help us to better understand the consequences of disease and various stressors that impact on their behaviour and reproductive potential. Additional health assessments and surveillance of pathogens in southeastern Florida's gopher tortoises are definitely required."

⮝ Living in burrows may facilitate a build-up in the number of ticks on gopher tortoises, which in turn can spread blood parasites. Photo courtesy Matthew Yoder/www.shutterstock.com

Further information

Annie Page-Karjian, Kathleen Rafferty, Clerson Xavier, Nicole I Stacy, Jon A Moore, Sarah E Hirsch, Samantha Clark, Charles A Manire, Justin R Perrault. **Comprehensive health assessment and blood analyte reference intervals of gopher tortoises (*Gopherus polyphemus*) in southeastern FL, USA.** *Conservation Physiology*, 2021; 9 (1) DOI: 10.1093/conphys/coab015

MEDITERRANEAN SEA TURTLES RECOVER

Sea turtles have been staging a welcome comeback in the Mediterranean over recent decades. Photo courtesy blue-sea.cz/www.shutterstock.com

Numbers of two Mediterranean turtle species have risen in the last three decades – but in Cyprus, it is clear, based on new research, that population recoveries are taking place at different rates. Nest counts at 28 beaches show green turtle (*Chelonia mydas*) nests increased by 162% from 1993 to 2019, while loggerhead (*Caretta caretta*) nests only rose by 46%.

The research team – from the University of Exeter in the UK, the Society for the Protection of Turtles (SPOT) and Eastern Mediterranean University – believe this difference in population growth is probably due to higher death rates among loggerhead turtles of all ages. Turtles in this region used to be hunted for meat and shells, but this is now banned throughout the Mediterranean region. Coupled with protection of their nesting beaches, these changes have since allowed populations to recover – but the scientists believe that better protection when the turtles are at sea is still required.

⮝ **Cyprus is located in the eastern Mediterranean, with the island shown here in red. It is an important location for turtles nesting in this part of the world.** Photo courtesy Harvepino with certain elements provided by NASA/www.shutterstock.com

⮝ **Green turtles are found in different habitat to loggerheads, grazing in areas of sea grass.** Photo courtesy Krzysztof Odziomek/www.shutterstock.com

Why the difference?

"The recoveries of these populations are very encouraging," says Dr Lucy Omeyer, of the Centre for Ecology and Conservation on Exeter's Penryn Campus in Cornwall. "However, the different rates of recovery suggest loggerheads face additional threats compared with those faced by green turtles.

"The sea grass diet of adult green turtles might partly explain this, as it means green turtles are less likely to be caught as bycatch (accidentally caught by fishing), because for most of their lives, they live in very specific habitats which are also protected. Green turtles are also more likely than loggerheads to return to the same nesting beaches, and stay close to the beach, while loggerheads move around in fishing grounds during the nesting season."

⮝ **There can be potential conflicts between tourism and turtles, as shown by the nesting location chosen by this loggerhead turtle.** Photo courtesy fotopanorama360/www.shutterstock.com

More help required

The study found 'stable' rates of reproduction among loggerheads, suggesting that deaths among turtles of all ages (rather than lack of hatchlings) is likely to be impeding the recovery of this species. Dr Damla Beton, of SPOT, points out: "Our other studies have found that many mature loggerheads die in fisheries when they visit Cyprus to breed, as well as in foraging grounds across the region. So it is therefore not surprising that this mortality is reflected in the nesting trends.

"Better understanding of their movements and the fisheries threats that they face could help inform conservation measures such as the creation of Marine Protected Areas."

There is no room for complacency either, even in the case of green turtles. Despite their recovery, their total population in the Mediterranean is estimated at just 3,400 adults, while their main breeding and foraging grounds are restricted to a handful of sites.

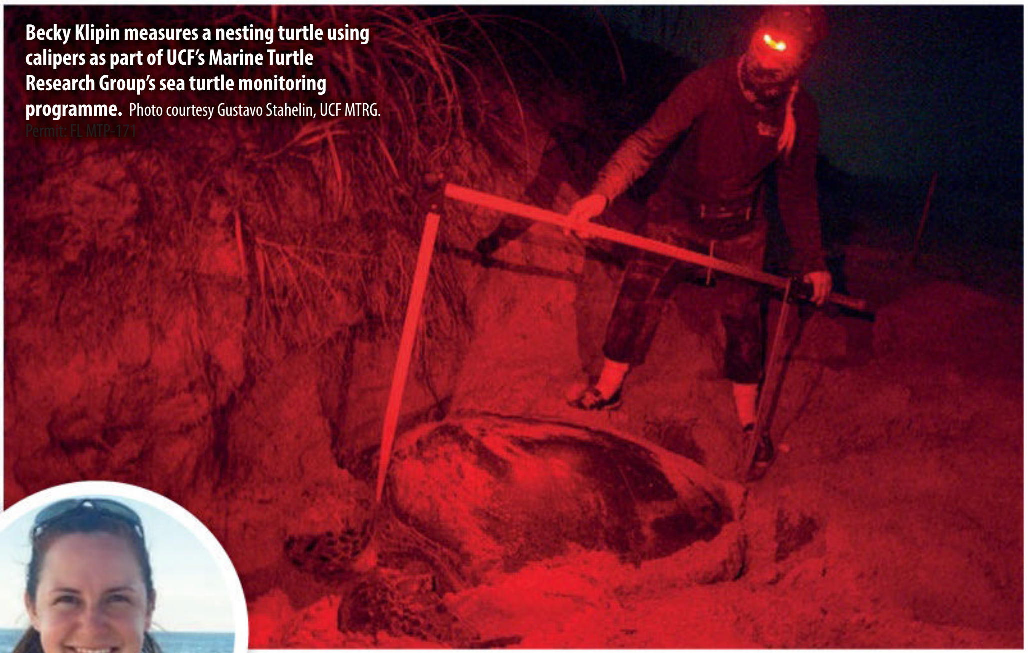
Further information

L. C. M. Omeyer, K. L. Stokes, D. Beton, B. A. Çiçek, S. Davey, W. J. Fuller, B. J. Godley, R. B. Sherley, R. T. E. Snape, A. C. Broderick. **Investigating differences in population recovery rates of two sympatrically nesting sea turtle species.** *Animal Conservation*, 2021; DOI: 10.1111/acv.12689

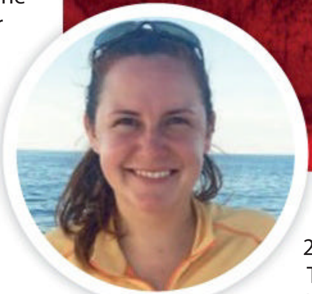
Smaller turtles nesting on Florida's beaches

A new University of Central Florida (UCF) study indicates that smaller loggerhead (*Caretta caretta*) and green sea turtles (*Chelonia mydas*) are nesting on Florida beaches than in the past; however, it is still not clear as to why this is the case. The findings also give clues to the status of the turtles, which is important to researchers who are monitoring the population health of these threatened species.

Central Florida's Atlantic coastline hosts about one-third of all green turtle nests in the state and represents one of the most important nesting areas in the world for loggerheads. The reason for the appearance of smaller nesting turtles is still a mystery though, according to Katrina Phillips.



Becky Klipin measures a nesting turtle using calipers as part of UCF's Marine Turtle Research Group's sea turtle monitoring programme. Photo courtesy Gustavo Stahelin, UCF MTRG. Permit: FL MTP-171



Katrina Phillips, who headed this study. Photo courtesy Katrina Phillips.

A large-scale survey

"It might be that juvenile turtles are growing more slowly because they are having a harder time finding food as a result of habitat degradation or facing competition from other turtles," Phillips says. "Or smaller turtles may also be new recruits to the population as a result of successful sea turtle conservation efforts. At present, we don't know why we're seeing more small turtles nesting."

The researchers made the discovery by comparing the shell lengths of nearly 10,000 nesting female loggerheads and more than 3,000 nesting female green turtles. The measurements were collected by UCF's Marine Turtle Research Group over the course of a period of 37 years, from 1982 to 2019.

The nesting turtles were observed in the Brevard County portion of the Archie Carr National Wildlife Refuge. Age is not recorded or known because it requires examining a cross-section of the turtle's leg bone, which would obviously not be possible, and even then, at best, the age of the turtle would still be an estimate.

Sea turtles are important as iconic symbols of conservation in Florida and for the role they play in maintaining a healthy ocean ecosystem. Photo courtesy Lawrence Cruciana/www.shutterstock.com

Long-term monitoring

The researchers found that the average size of nesting loggerheads decreased by nearly 2.5cm (1in) and the average size of nesting green sea turtles has fallen by more than 3.75cm (1.5in) since 1982. As well as raising questions about why the turtles are smaller, the findings also mean that when estimating female sea turtle maturity based on size, researchers and management agencies will need to consider smaller turtles in their estimates in future.

"The numbers we provide for the minimum size range of mature females will assist other groups who study turtles at sea, where it's not clear if they are mature or not, helping them to better estimate which of theirs are juveniles," she says.

The extensive study was made possible by the long-time work of UCF's Marine Sea Turtle Research Group. The monitoring project was started in 1982 by UCF Professor Emeritus and Pegasus Professor of Biology Llewellyn "Doc" Ehrhart.

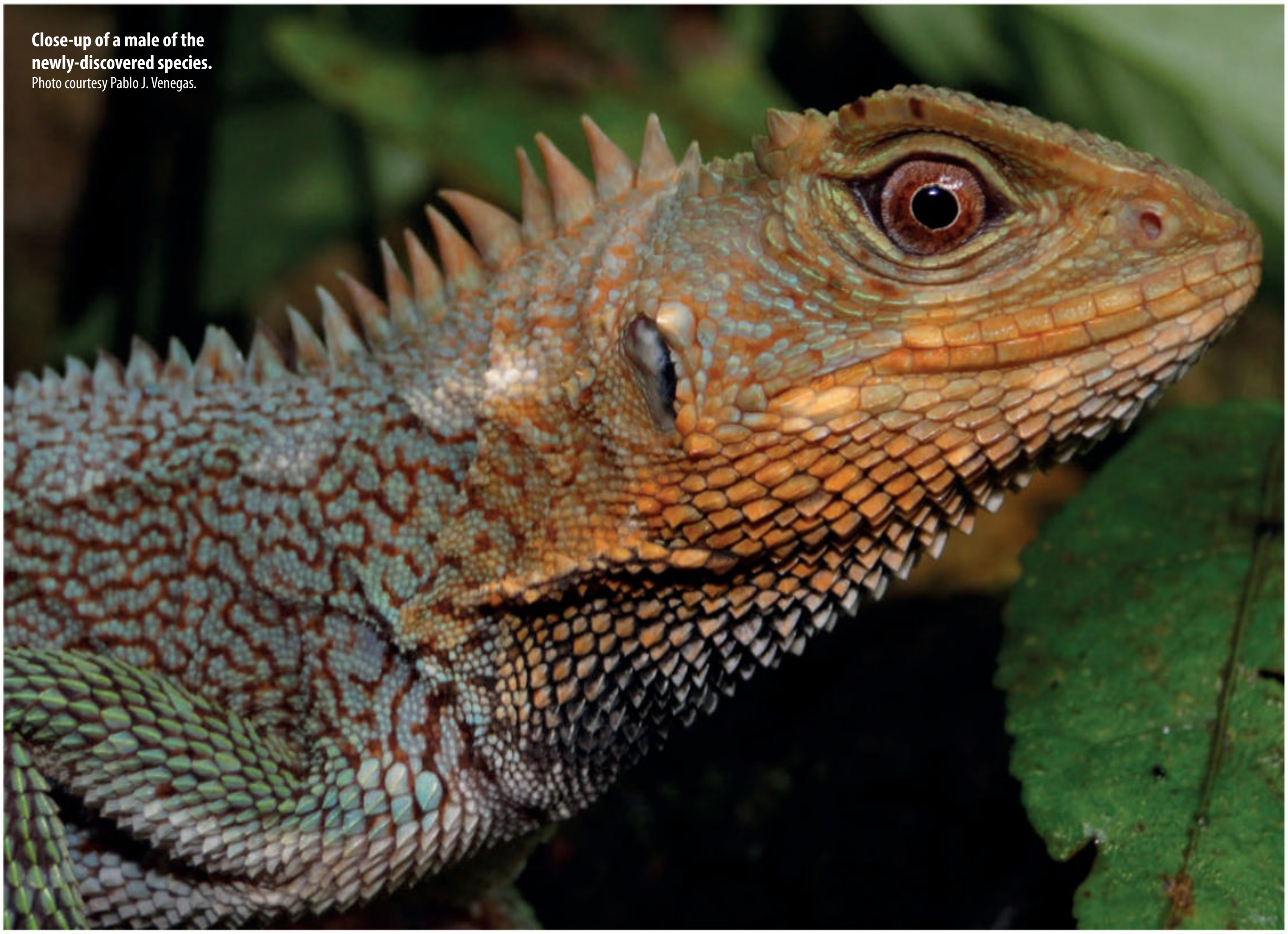
"Many nesting beach projects take these measurements, but the UCF project is unique because of how long it's been going on and how many turtles come ashore to nest here," Phillips says. "Florida has more loggerhead nests than anywhere else in the world, and the green turtle nest numbers are also rising."

Legal and practical protection for nest sites on Florida's beaches may have contributed to an increase in turtle numbers. Photo courtesy Leigh Trail www,shutterstock.com

Further information

Katrina F. Phillips, Gustavo D. Stahelin, Ryan M. Chabot, Katherine L. Mansfield. **Long-term trends in marine turtle size at maturity at an important Atlantic rookery.** *Ecosphere*, 2021; 12 (7) DOI: 10.1002/ecs2.3631

New stunning dragon-like lizard discovered



Close-up of a male of the newly-discovered species.
Photo courtesy Pablo J. Venegas.

One of the most biodiverse and fascinating areas for wildlife in the world lies in the vicinity of the Huallaga River, located in the Andes of central Peru. This river extends for 1,138 km (700ml), making it the largest tributary of the Marañón River, which is effectively the spinal cord of the Amazon. This region harbours a range of different ecosystems, including the Peruvian Yunga ecoregion, which is home to many endemic birds, mammals, reptiles and amphibians.

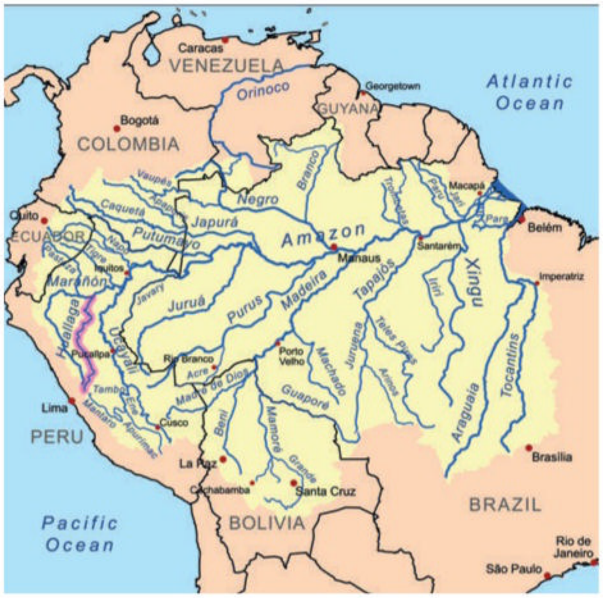
Regaining control

How is it possible, then, that this corner of the tropical Andes remains poorly known to biologists to this day? The main reason is quite simple and it lies in the civil wars involving terrorist organisations and drug traffickers that were taking place in the region during the 1980s, which disrupted biological studies.

It wasn't until the late 1990s that the Peruvian government was able to gain control of the area, and that's when, little by little, some biologists began to venture back to the Huallaga Valley. However, forest destruction caused by coca plantations during the bitter civil war, which eventually led to the construction of a hydroelectric power plant, left the Huallaga valley highly fragmented, making for an even more urgent need for biodiversity research in the area.

The latest discovery

A new species of wood lizard, now known as *Enyalioides feiruzae*, was recently confirmed from the lower-level forest within the Huallaga river basin. It took the researchers seven years of field surveys in order to be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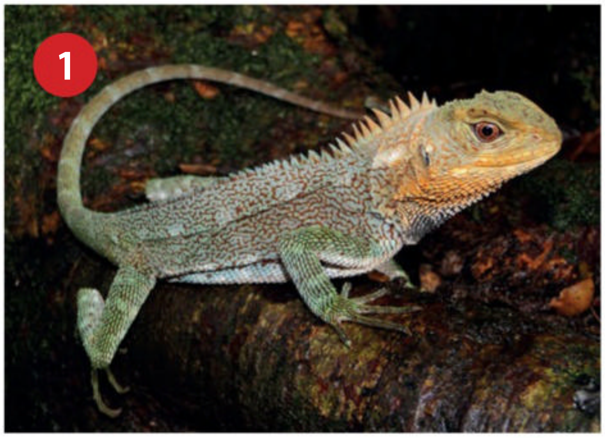
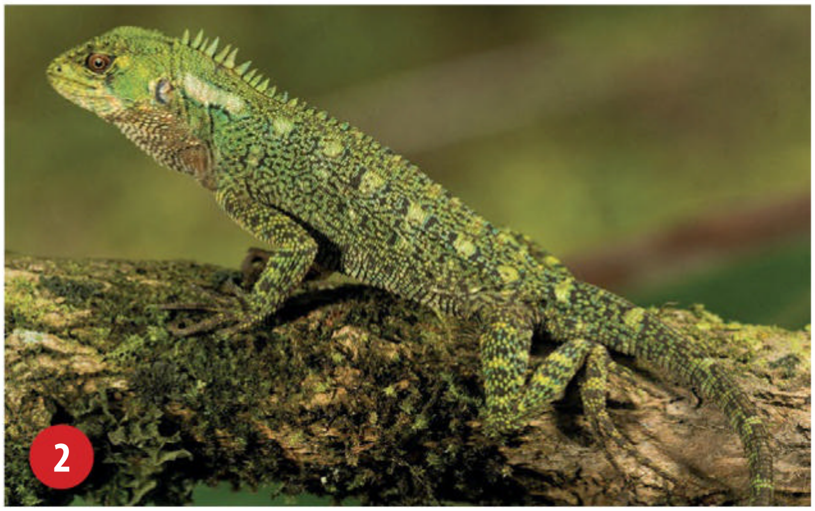
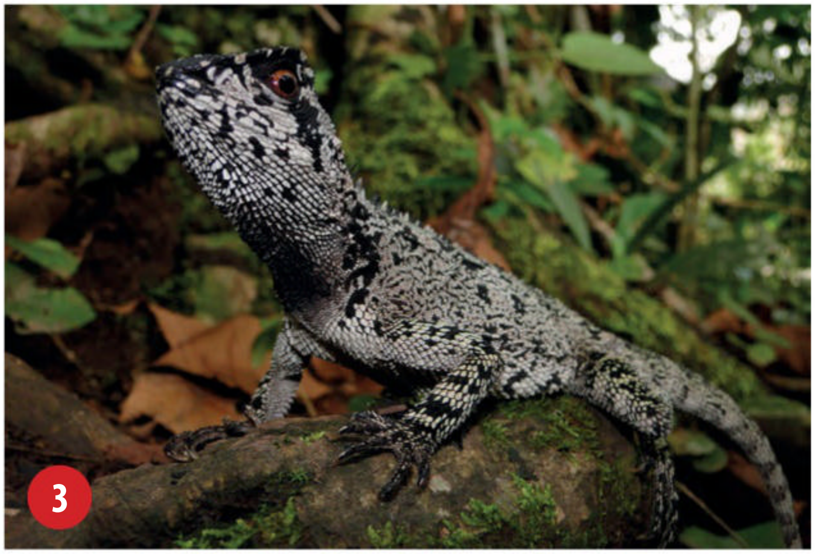
Paru
Jari
Macapá
Pará
Belém
Quito
ECUADOR
Caquetá
Japurá
Putumayo
Napo
Tigre
Pastaza
Iquitos
Marañón
Amazon
Manaus
Santarém
Xingu
Iriri
Imperatriz
Javary
Juruá
Purus
Madeira
Tapajós
Huallaga
Ucayali
Pucallpa
Rio Branco
Acre
Porto Velho
Machado
Juruena
Teles Pires
Arinos
Tocantins
Araguaia
Tambo
Ene
Mantaro
Apurímac
Madre de Dios
Guaporé
Lima
Cusco
PERU
Beni
Mamoré
Grande
La Paz
Cochabamba
Santa Cruz
Brasilia
BRAZIL
BOLIVIA
Pacific Ocean
Rio de Janeiro
São Paulo

⮝ **The course of the Huallaga River, highlighted in purple.**
Source Kmusser - own work using Digital Chart of the World & GTOPO data/Wikipedia/CC BY-SA 3.0







⮝ **1-3 Male specimens of the Feiruz wood lizard, showing the extreme variation in appearance between males that occurs within this species.** Photo courtesy Pablo J. Venegas.

able to describe it. They first had to spend long periods in the forests, in order to catch these lizards that were sleeping on bushes between 20–150cm (8-59in) above the ground.

The new species has been placed in the genus *Enyalioides*, which now contains 16 species. More than half of the known members of this group have been described in the last two decades, largely as the result of recent surveys of remote places in the tropical Andes from Ecuador and Peru.

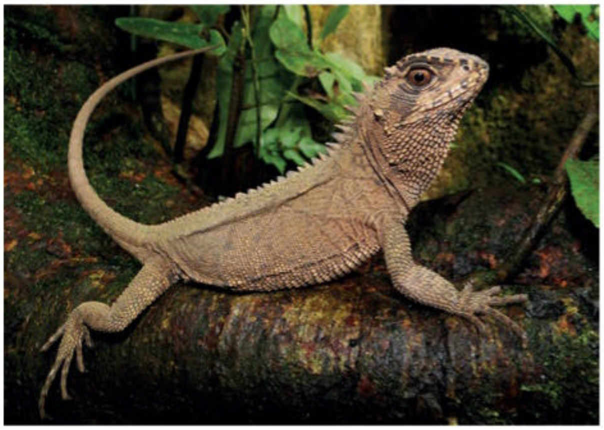
Variable in appearance

Feiruz wood lizards – especially the males – come in a stunning variety of colours. Males can have brownish-turquoise, grey, or greenish-brown backs traced with pale lines. Females, in contrast, can be greenish-brown or floury brown, with faint dark brown lines on their back, limbs and tail, and spots on the sides.

The researchers believe *E. feiruzae* may have become established as a separate species after it became geographically separated from a very similar lizard, *E. rudolfarndti*, possibly as a result from tectonic activity and climatic oscillations that occurred from the Late Oligocene to the Early Miocene around 20 million years ago.

The Feiruz wood lizard was named after Feiruz – described as "a female green iguana, muse and lifelong friend". Catherine Thomson, who was Feiruz's owner, supported the efforts of the scientists in their work in the fields of taxonomic research and nature conservation.

⮜ **Just a single population of the new species falls within the protected boundaries of the Tingo Maria National Park, with the town nearby.** Photo courtesy Milton Rodriguez/www.shutterstock.com



⮝ **An adult female. These are less colourful and varied in appearance, compared with males.** Photo courtesy Pablo J. Venegas.

Limited protection

The habitat of the newly discovered wood lizard is very fragmented, by agricultural land and pastures for cattle ranching. At present, only one protected population is known to exist within the boundaries of the Tingo Maria National Park. Much more remains to be discovered about the size and distribution of the Feiruz wood lizard populations and their ability to survive and adapt in what is an increasingly fragmented landscape.

Further information

Venegas PJ, Chávez G, García-Ayachi LA, Duran V, Torres-Carvajal O (2021) **A new species of wood lizard (Hoplocercinae, *Enyalioides*) from the Río Huallaga Basin in Central Peru.** *Evolutionary Systematics* 5(2): 263-273. https://doi.org/10.3897/evolsyst.5.69227

The survival of snakes

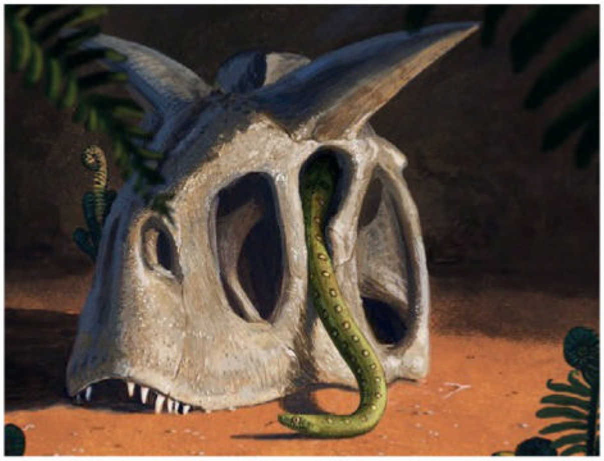
A new study suggests that all living snakes evolved from just a handful of species that survived the giant asteroid impact which wiped out the dinosaurs and many other living things at the end of the Cretaceous. The researchers believe that this devastating extinction event provided a form of 'creative destruction' that allowed snakes to diversify into new niches which had previously been filled by their competitors.

Growth in numbers

They highlight the fact that snakes, now numbering almost 4000 living species today, actually started to diversify about the time of this extra-terrestrial impact. The study, led by scientists at the University of Bath and including collaborators from Bristol, Cambridge and Germany, used fossils and analysed genetic differences between modern snakes to reconstruct snake evolution. This information then helped to pinpoint the time that modern snake lineages evolved.

It is likely that the ability of snakes to shelter underground and go for long periods without food helped them to survive the destructive effects of the meteor impact. In the aftermath, the extinction of their competitors – including Cretaceous snakes and the dinosaurs themselves – allowed the survivors to move into new niches, and spread to new habitats and new continents.

Image courtesy solarseven/www.shutterstock.com



⮝ **The extinction of their competitors allowed snakes as a group to develop and evolve new lifestyles.** Image courtesy Joschua Knüppe.

Changing shape

Snakes then began to diversify, producing lineages like vipers, cobras, garter snakes, pythons, and boas, exploiting new habitats, and new prey. Modern snake diversity – including tree snakes, sea snakes, venomous vipers and cobras, and huge constrictors like boas and pythons – emerged only after the dinosaur extinction.

Fossils also show a change in the shape of snake vertebrae in the aftermath, resulting from the extinction of Cretaceous lineages and the appearance of new groups, including giant sea snakes up to 10m (33ft) long.

"It's remarkable, because not only are they surviving an extinction that wipes out so many other animals, but within a few million years they are innovating, using their habitats in new ways," says Dr Catherine Klein, who now works at Friedrich-Alexander-Universität Erlangen-Nürnberg (FAU) in Germany.

The study also suggests that snakes began to spread across the globe around this time. Although the ancestor of living snakes probably lived somewhere in the Southern Hemisphere, snakes first appear to have spread to Asia after the mass

The diversity in snakes today is shown by the range of habitats that they occupy, extending into the ocean. This is a banded sea snake.
Photo courtesy Rich Carey.

➤ **Green anacondas (*Eunectes murinus*) rank amongst the largest snakes alive today, although bigger snakes used to exist in South America, with titanoboa growing to a length of at least 12.8m (42ft), which is more than double that of an anaconda. It lived just after the Cretaceous mass extinction event.**
Photo courtesy Holger Kirk/www.shutterstock.com

extinction event occurred.

Disaster encourages change

Dr Nick Longrich, from the Milner Centre for Evolution at the University of Bath says: "Our research suggests that extinction acted as a form of 'creative destruction'- by wiping out old species, it allowed survivors to exploit the gaps in different ecosystems, experimenting with new lifestyles and habitats.

"This seems to be a general feature of evolution - it's the periods immediately after major extinctions where we see evolution at its most wildly experimental and innovative. The destruction of biodiversity makes room for new things to emerge and colonise new landmasses. Ultimately life becomes even more diverse than before."

The study also found evidence for a second major diversification event around the time that the world shifted from a warm 'greenhouse earth' into a colder 'icehouse' climate, which saw the formation of polar icecaps and the start of the Ice Ages. These patterns seen in association with snakes hint at a key role for catastrophes - severe, rapid, and global environmental disruptions - in driving evolutionary change.

An Aesculapian snake (*Zamenis longissimus*) – a colubrid species – seen in its forest home in Italy.
Photo courtesy Marco Maggesi/www.shutterstock.com

Further information

Catherine G. Klein, Davide Pisani, Daniel J. Field, Rebecca Lakin, Matthew A. Wills & Nicholas R. Longrich (2021) **Evolution and dispersal of snakes across the Cretaceous-Paleogene mass extinction**, *Nature Communications* DOI: 10.1038/s41467-021-25136-y

Resistant lizards

➤ **The eastern blue-tongue skink.**
Photo courtesy Ken Griffiths/ www.shutterstock.com

Scientists have discovered that the eastern blue-tongue skink (*Tiliqua s. scincoides*) is largely resistant to the venom of the deadly red-bellied black snake (*Pseudechis porphyriacus*), while giant carnivorous monitor lizards (*Varanus species*) which feed on Australia's most venomous snakes are not immune to its venom.

This surprising finding was revealed after University of Queensland scientists compared the effects of various reptile blood plasmas when exposed to the venom. Investigator Nicholas Youngman explains that mammalian – and particularly, human – reactions to it had been heavily investigated, but very little was known about the effects of snake venom on other reptiles.

➤ **The venom of the red-bellied black snake was the subject of this study.**
Photo courtesy Ken Griffiths/ www.shutterstock.com

▲ **The shingleback also proved to share the eastern blue-tongue's resistance to the snake's venom.** Photo courtesy Ken Griffiths/www.shutterstock.com

How the protection works

"It was a shock, finding that the eastern blue-tongue along with the shingleback (*T. rugosa*) showed resistance specifically to red-bellied black snake venom," Mr Youngman admits. "Since their resistance was so specific to only this snake species, it seems these lizards have evolved a special plasma component – known as a serum factor – in their blood.

"This prevents specific toxins in red-bellied black snake venom from clotting the lizards' plasma, which would lead to a rapid death in most other animals. Its resistance doesn't mean they're completely immune, but it would give them a greater chance of survival, allowing them to escape or fight back. It's rather similar to a COVID-19 vaccine: it doesn't actually prevent you getting sick, but it should mean you are less likely to die."

The research team analysed the effects of seven different Australian snake venoms on the plasma of two species of blue-tongued skink and three species of monitor lizard that would interact with these snakes in the wild.

▼ **The tough skin of goannas provides them with protection from snake bites.** Photo courtesy Ken Griffiths/www.shutterstock.com

A different means of defence

Associate Professor Bryan Fry, who heads UQ's Venom Evolution Lab, explains the results also revealed that monitor lizards – or goannas – were not resistant to the snake venoms. "You'd think that a goanna would be significantly resistant to the venom of any snake it was hunting and eating, but that isn't the case," Dr Fry says.

"Snake venom can only cause harm to goannas if it's injected into the body by the snake's fangs. It can't be absorbed directly through the skin. Goannas are heavily armoured and their scales act like medieval chain mail, with each containing a piece of bone, meaning that the fangs of venomous snakes struggle to pierce this armour.

"So – unlike the slow, vulnerable blue-tongue lizard – there's no pressure for goannas to evolve resistance; natural selection has invested in their armour and it's clearly working for them. These two divergent forms of resistance to snake venom are fascinating examples of different evolutionary solutions to the same problem."

Further information

Nicholas J. Youngman, Joshua Llinas, Bryan G. Fry. **Evidence for Resistance to Coagulotoxic Effects of Australian Elapid Snake Venoms by Sympatric Prey (Blue Tongue Skinks) but Not by Predators (Monitor Lizards)**. *Toxins*, 2021; 13 (9): 590 DOI: 10.3390/toxins13090590

Crash–landing geckos

In more than 15 years of research on geckos, scientists at the University of California, Berkeley, and, more recently, the Max Planck Institute for Intelligent Systems in Stuttgart, Germany, have shown that geckos use their tails to manoeuvre in midair when gliding between trees. This allows them to right themselves when falling, to keep from falling off a tree when they lose their grip and even to propel themselves across the surface of a pond, as if walking on water. Many of these techniques have since been implemented in agile, gecko-like robots.

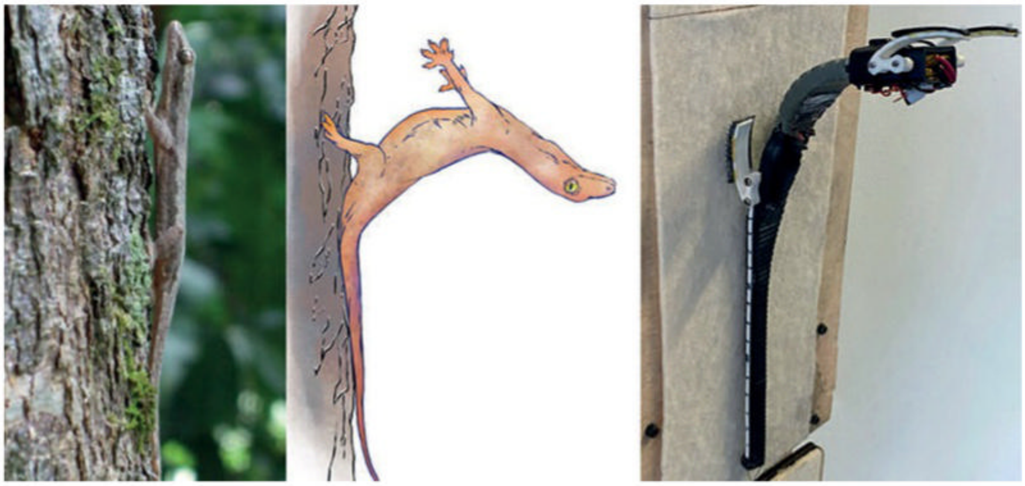
Tails assist crash-landings

Robert Full, UC Berkeley professor of integrative biology, and Ardian Jusufi, at the Max Planck Research School for Intelligent Systems and former UC Berkeley doctoral student, were amazed by a recent discovery: geckos also use their tails to help recover when they take a header into a tree.

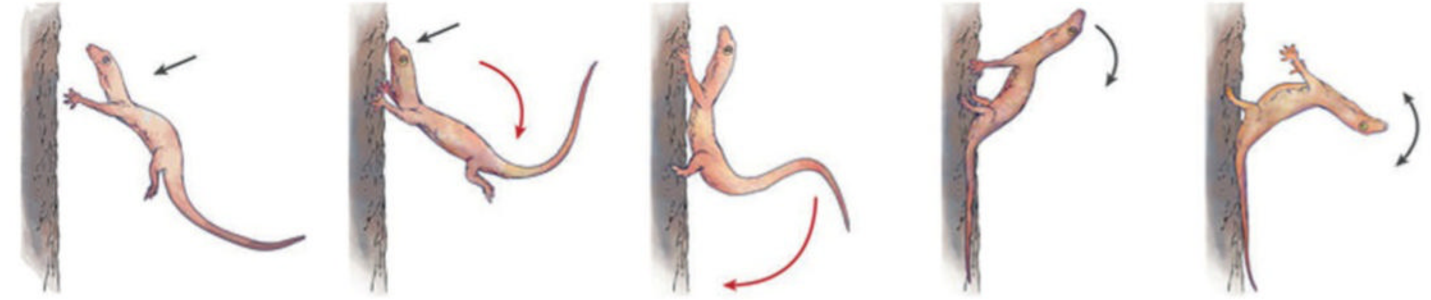
Those head-first crashes are almost certainly not the geckos' preferred landing, but Jusufi documented many such hard landings in 37 glides over several field seasons in a Singapore rainforest, using high-speed video cameras to record the lizards' trajectories and wince-inducing landings. He clocked their speed upon impact at about 6 metres per second, or 21 kilometres per hour — more than 200 feet per second, or about 120 gecko body lengths per second.

Observing the geckos from elevation in the rainforest canopy was eye-opening. Before take-off, they would move their head up-and-down, and side-to-side to view the landing target prior to jumping off, as if to

The Asian flat-tailed house gecko was the species that the researchers studied. Photo courtesy reptiles4all/www. shutterstock/com



⌃ **The Asian flat-tailed house gecko aims to execute a four-point landing after leaping to a tree trunk, but if it can't slow down sufficiently, it may have to crash headfirst into the trunk, rebounding but stabilising itself with its tail. Researchers at the Max Planck Institute for Intelligent Systems in Germany built a soft robot with an active tail to replicate this behaviour.** Photos courtesy Ardian Jusufi/ illustration by Andre Wee.



⌃ **A sequence commonly observed in the tropical rainforest — a gecko colliding head-on with a tree trunk, but using its tail to recover from the crash-landing. The researchers refer to this as the gecko's fall-arresting response.** Sketches courtesy of Andre Wee.

estimate the travel distance," Jusufi says.

How the landing may occur

The videos show that when this gecko — the common Asian flat-tailed house gecko (*Hemidactylus platyurus*) — collides head-on with a tree, it grabs the trunk with its clawed and padded toes so that, as its head and shoulders rebound, it has leverage to press its tail against the trunk to prevent itself from tumbling backward onto the ground and potentially ending up as someone's dinner.

"Far from stalling, some of these lizards are still accelerating upon impact," Jusufi explains. "They crash headfirst, pitching back head over heels at an extreme angle from the vertical — they look like a bookstand sticking away from the tree! — anchored only by their rear legs and tail as they dissipate the impact energy. With the fall-arresting reflex happening so fast, only slow motion video could reveal the underlying mechanism."

Robotic mimics

This surprising behaviour has been replicated by robots with tails that act similarly, confirming how the lizards successfully recover from crash landings. Though this type of headfirst crash landing has not been documented previously among geckos or other gliding animals, the scientists suspect that other small, lightweight leapers — in particular, other lizards — use this as a backup when a perfect jump is impossible.

"They may have longer glides that are more equilibrium glides, and they land differently, but, for example, if they are trying to escape, they choose to behave in this way because in part, size matters," Full says, noting that the lizards measure only about 5cm (2in) from snout to tail tip.

"When you're that small, you have options that aren't solutions for big things. So, this is a type of body-mediated solution that you don't have if you're bigger."

Jusufi and Full note that structures similar to gecko tails could be used to help stabilise flying robots, such as drones, when they land on vertical surfaces. According to the researchers, this unusual behaviour (which they're the first to document, mathematically model and reproduce in a soft robot), is an example of how an evolutionary innovation like a tail can be used in unforeseen ways.

What a tail can offer

Vertebrate tails evolved in aquatic animals, probably as a means of propulsion in the water — something Jusufi also studies and models with soft robots that undulate. But the tail turned out to be such a versatile thing that the lizard evolved various exaptations, which is a term used for structures that were shaped by natural selection for a particular function or adaptation, but that have also been used for other behaviours.

"Exaptations are structures that have been co-opted for many behaviours, no matter what that structure evolved for originally, and here's one that you wouldn't expect," Full admits. "You can see how that incredible capability of being robust can allow these exaptations."

"Until recently, tails had not received as much attention as legs or wings, but people are now realising that we should think of these animals as five-legged, in a way — or pentapedal," argues Jusufi.

Full said that as robotic engineers attempt to add more and more functions to robots, they are finding that they can't introduce a new part for every capability. A tail is one structure that, as lizards found out, can have multiple purposes.

"As we evolve our robots and physical systems, engineers all want to do more things. And guess what? At some point, you can't optimise a robot for everything," he explains. "You have to use things for other behaviours in order to achieve those additional behaviours."

A robot catapult

In Singapore, Jusufi and his colleagues used high-speed cameras to record geckos leaping across to trees that were too close to allow gliding. Even though the flat-tailed gecko is not particularly adapted to gliding — some geckos have skin flaps that are like parachutes – it has an ability to glide and thus manoeuvre in midair.

But gliding requires reaching sufficient velocity so that the lizard can manoeuvre in this way, and the leaps weren't long enough for that to be achieved. Unable to glide or slow

➤ **The gecko may sometimes have no other opportunity when confronted by a predator other than to jump, under less than ideal circumstances.**
Photo courtesy kampol Jongmeesuk/www.shutterstock.com

⮝ **A tokay gecko jumping from a branch. It is suspected that this species (and other small arboreal lizards) may jump in a similar way to the Asian flat-tailed house gecko.**
Photo courtesy 249 Anurak/www.shutterstock.com

⮟ **The Asian flat-tailed house gecko is common in the forests of Singapore. High-speed videos of these geckos leaping from tree to tree showed that their tails allow them to recover effectively from crash landings on vertical tree trunks.**
Photo courtesy of Ardian Jusufi.

⮝ **These geckos have relatively long tails, compared with their body length, as seen here.**
Photo courtesy Putase/www.shutterstock.com

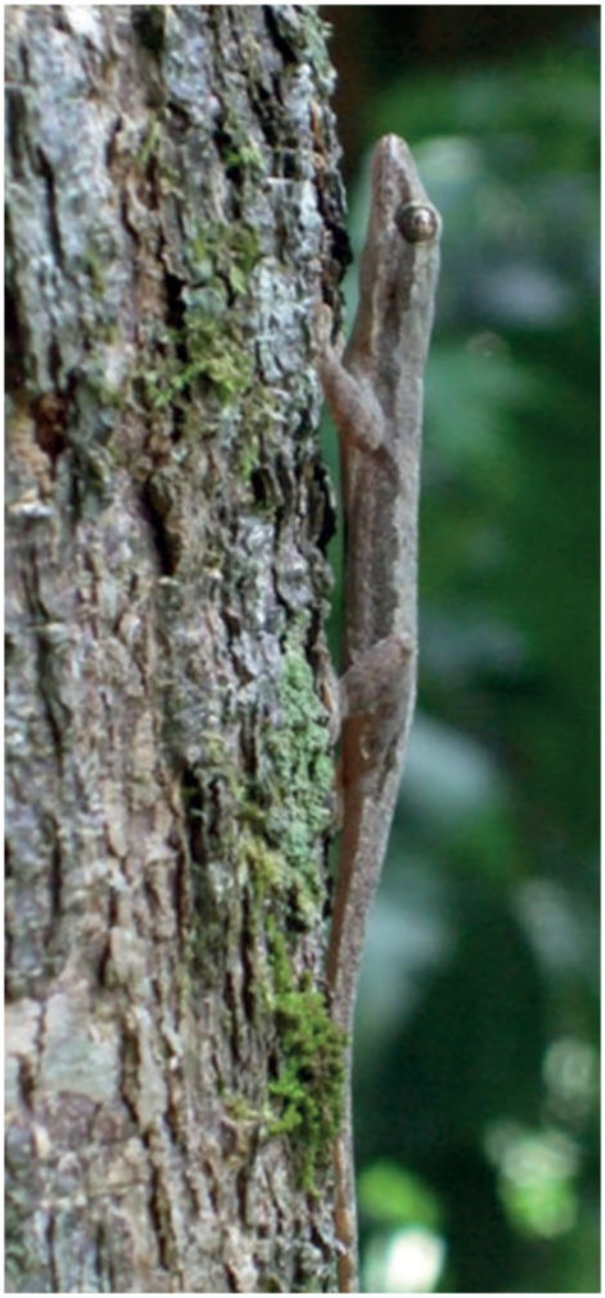
themselves by stalling before landing, the geckos therefore crashed hard, usually headfirst.

When they analysed the trajectories and mechanics of the falling geckos, the researchers found that some were still accelerating on impact. Most could not maintain a grasp on the tree with their front feet.

A previously unsuspected skill

"Our field observations of these small, agile lizards in the rainforest revealed highly dynamic, fall-arresting responses nobody thought these geckos could execute with their tails," Jusufi says. "Our field observations suggest they exapted tail behaviour thought to be for climbing to perching after gliding flight."

➤ Ardian Jusufi (left) and Rob Siddall with an arboreal, lizard-inspired robot on a tree trunk in the lab of Jusufi's Locomotion in Biorobotic and Somatic Systems Group in Stuttgart, Germany. Photo courtesy Wolfram Scheible.



⮟ An Asian flat-tailed house gecko after landing safely on a tree trunk. Photo courtesy Ardian Jusufi.

The researchers modelled the behaviour mathematically to confirm that what they were seeing made sense physically. But to determine what the geckos were experiencing, they decided to build a soft robot at the Max Planck Institute that resembles a gecko and launch it with a catapult into the wall. This way, they could measure the forces actually sustained by the geckos when they crash-land, and the forces produced by the feet.

The team constructed the tailed robot from parts made by a state-of-the art 3D printer, Carbon M2, that is specifically designed to print soft structures. The feet were outfitted with Velcro® to stick upon contact, and to the tail they added a mechanism that would make it press downward when the front legs hit a surface and slip, corresponding to the gecko's tail reflex.

Comparisons between geckos and robots

Surprisingly, the tailed robot had similar success when making hard landings. In the wild, 87% of geckos with tails successfully landed on a vertical surface without falling, while tailless geckos fell more frequently. (Geckos of course often shed their tails to escape from predators or their rivals, and regrow them later.) Tailless robots were only able to land successfully on a vertical surface in 15% of the trials, compared to 55% of trials involving the tailed robot.

The researchers also found that, beyond a certain length, longer tails aren't necessarily that much better than shorter tails. Robots with tails only half the length of the head and body combined were nearly as successful as those with tails equal to the snout-vent length. Short-tailed robots, however, required twice the foot force to stay attached to the tree.

Full and Jusufi continue to study the behaviour of geckos in search of principles that can be applied to the design of robots — in particular, soft robots that can perch in trees and land on vertical surfaces — but also to explore the evolutionary origins of animal locomotion. One key message, Full said, is that, while engineers may seek to design the optimal robot, nature never does.

How life works!

"Evolution is not about optimality and perfection, but instead, it's about sufficiency. The 'just-good-enough' solution really plays into giving you a breadth of capabilities so that you're far more robust in challenging environments," Full explains. "Evolution looks more like a tinkerer who never really knows what they'll produce and uses everything that's at their disposal to make something into a workable model!"

"Small arboreal animals without obvious morphological adaptations for flight are increasingly being found to exhibit surprising ability for mid-air manoeuvring. Soft robotic physical models can help decipher the control of such mechanically mediated solutions to landing," adds Jusufi.

Further information

Robert Siddall, Greg Byrnes, Robert J. Full & Ardian Jusufi. **Tails stabilize landing of gliding geckos crashing head-first into tree trunks.** Communications Biology, 2021 DOI: 10.1038/s42003-021-02378-6

A new resident in Florida?

Caecilians have arrived in Miami with Florida Fish and Wildlife biologists having captured one of the little-known legless amphibians in the Tamiami Canal. It is the first example of an introduced caecilian recorded in the US.

Florida Museum of Natural History scientists then used DNA testing to confirm the identify the specimen as the Rio Cauca caecilian, (*Typhlonectes natans*), which is a native of Colombia and Venezuela. While caecilians – pronounced like "Sicilians" – hunt and scavenge various kinds of small animals, notably worms, museum experts say it's too early to predict their potential impact on the local ecosystem.

"Very little is known about these animals in the wild, but there's nothing particularly dangerous about them, and they don't appear to be serious predators," says Coleman Sheehy, Florida Museum's herpetology collection manager. "They'll probably eat small animals and get eaten by larger ones. This could be just another non-native species in the South Florida mix."

More than one

Sheehy first learned of the caecilian when FWC officers sent him a photograph in 2019, puzzled by an eel-like animal measuring some 60cm (2ft) in length that they had netted in shallow water during a routine survey of the Tamiami Canal, also known as the C-4 Canal. After the caecilian died in captivity, it was sent to the Florida Museum for further analysis.

Since then, Sheehy has received several other specimens and reports of caecilians in the canal and will conduct fieldwork in the area to determine their numbers and range. "At this point, we really don't know enough to say whether caecilians are established in the C-4 Canal," he said. "That's what we want to find out."

What are they?

Little is known about this group of reclusive animals. Many caecilians spend their lives burrowed underground while others, including *Typhlonectes natans*, exclusively inhabit fresh water. Although they resemble worms or snakes, they comprise a separate order of amphibians, distinct from frogs, toads, salamanders and newts.

Caecilians can grow up to 1.5m (5ft) long, depending on the species, and have extremely poor eyesight – their name translates as "blind ones." They also have a pair of sensory tentacles located between their eyes and nostrils; these are structures that are unique to caecilians and may help them to find food.

Range and habitat

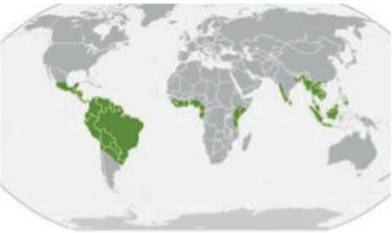
The northern tip of their distribution in the western hemisphere is southern Mexico, which is home to a number of land-dwelling caecilians, and members of the group are also found in tropical parts of Africa and Southeast Asia. Fossil remains of ancient caecilian ancestors, dating back more than 170 million years, have been discovered in the American Southwest.

Yet apart from the caecilians that were seemingly recently introduced to southern Florida, no representatives of this lineage are to be found in the US today. "This was not on my radar," Sheehy admits. "I didn't think we'd one day find a caecilian in Florida. So this was a huge surprise."

The Rio Cauca caecilian (*Typhlonectes natans*) closely resembles another, more widespread South American species, the Cayenne caecilian (*Typhlonectes compressicauda*). Researchers relied on DNA to confirm its identity. Photo courtesy Noah Mueller.

Typhlonectes natans is a species that may be kept occasionally and will breed in collections, giving birth to live young. As it is generally housed in aquariums indoors, however, and can't easily escape, Sheehy suspects that someone discarded their unwanted pets in the canal.

In its native range, *Typhlonectes natans* lives in warm, slow-moving bodies of shallow water with aquatic vegetation. "Parts of the C-4 Canal are just like that," Sheehy says. "So this may be an environment where this species can thrive."



➤ **The current range of the world's caecilians.** Map courtesy maplab/data from: Cogger, H.G & Zweifel, R.G. (1998). *Reptiles & Amphibians*. ISBN 0121785602/Wikipedia/ CC BY-SA 3.0

⮝ One of the few fully aquatic caecilians, *Typhlonectes natans* has lungs and can breathe air, but the majority of its respiration probably happens through its skin, says herpetologist Coleman Sheehy. Photo courtesy Noah Mueller.

Further reading

Coleman Sheehy, David Blackburn, Marcel Kouete, Kelly Gestring, Kristin Laurie, Austin Prechtel, Eric Suarez, Brooke Talley. **First record of a caecilian (order Gymnophiona, *Typhlonectes natans*) in Florida and in the United States.** *Reptiles & Amphibians*, 2021; 28 (2): 355 DOI: 10.17161/randa.v28i2.15629

Investigating sticky toe pads

Many lizards are phenomenal climbers. Their sharp, curved claws are ideal for clinging to tree trunks, rocks and other rough surfaces. However, in the precarious world of tree tops — filled with slippery leaves and unstable branches — three specific groups of lizards possess a remarkable evolutionary accessory: sticky pads on their fingers and toes.

Sticky toe pads have independently evolved in geckos, skinks and anoles — producing tree acrobats specially adapted to life in the forest canopy. Scientists have long considered sticky toe pads to be an "evolutionary key innovation" that allow arboreal lizards to interact with the environment in ways that many pad-less lizards cannot.

➤ Anoles are one of the groups of lizards that have evolved toe pads.
Photo courtesy John Slawik/ www.shutterstock.com

A worldwide study

Yet, some lizards without toe pads have adopted the canopy lifestyle — an observation that has puzzled scientists for decades. US biologists Aryeh Miller and James Stroud at Washington University in St. Louis recently set out to discover if lizards with toe pads had an evolutionary advantage for life in the trees, compared with their pad-less counterparts.

They analysed data from 2,600 lizard species worldwide and discovered that, while hundreds of different types of lizards have independently evolved arboreal lifestyles, species that possessed sticky toe pads prevailed.

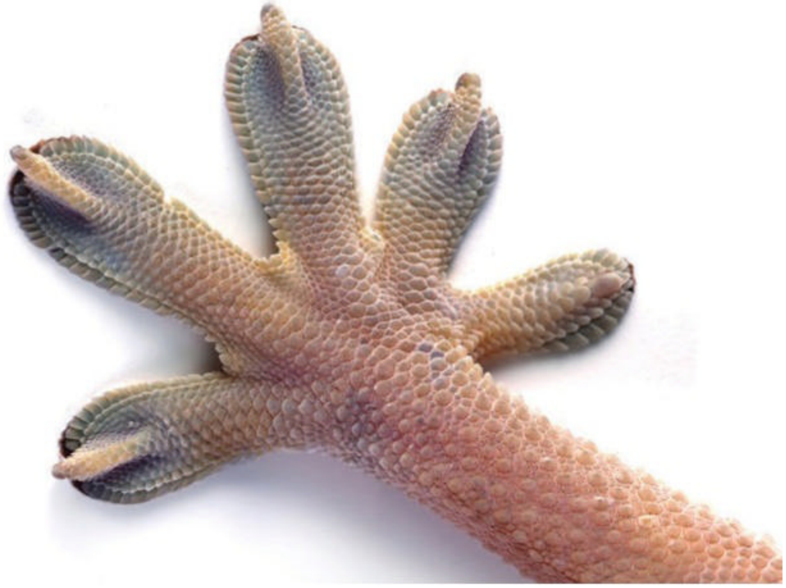
"Lizards with toe pads have a greater ecological advantage in the arboreal environment," says Miller. "Toe pads are essentially a biological supertool for lizards to access new resources that those without toe pads cannot manage to do."

"We found that lizards with sticky feet dominate the arboreal environment. Once adapted to life in the trees, they rarely leave," adds Stroud. "Conversely, lizards without sticky toe pads frequently transition away from living in trees to spending their time on the ground."

Shaping diversity

"Scientists have long wondered about the role that the origin of key innovation plays in subsequent evolutionary diversification. Lizards are an excellent type of organism for such studies because of the number of species that exist and the incredible extent of anatomical variation and habitat use," explains Professor Jonathan Losos who is based at Washington University.

Using a recently published database of habitat use for nearly every lizard species across the globe, the researchers were able to perform a comprehensive analysis of toe pad evolution in the context of lizard habitat use. For the first time, the evolutionary relationships between which lizards live in trees and those which do not has been clarified.



➤ A gecko toe pad viewed from above.
Photo courtesy Kurit afshen/ www.shutterstock.com

➤ Researchers Aryeh Miller (left) and James Stroud.
Photo courtesy Washington University.

◀ Professor Losos gets a close-up view of a subject in the study.
Photo courtesy Washington University.

➤ The fused toes of chameleons offer a different approach to arboreal life.
Photo courtesy Oakland Images/www.shutterstock.com

"Miller and Stroud have developed an exciting new approach to understanding this diversity and the role that anatomical evolution plays in shaping the great diversity of lizard kind. This work will be a model for researchers working on many types of plants, animals and microbes in the future," adds Losos.

Pads offer benefits

Miller, who led the analysis, is the first to discover that species have evolved for specialised life in trees at least 100 times in thousands of lizards. In other words, it is evolutionarily easy for a lizard to become a tree lizard.

What's difficult is sticking around! Toe pads don't evolve until after lizards get into the trees, not before. And padless lizards will leave trees at a high frequency — much higher than those which have developed toe pads.

"There are hundreds of different species of lizards living in the trees, but over evolutionary time many of those species end up leaving for life on the ground because, presumably, they interact with others with toe pads that have a greater advantage," Stroud suggests.

Further research

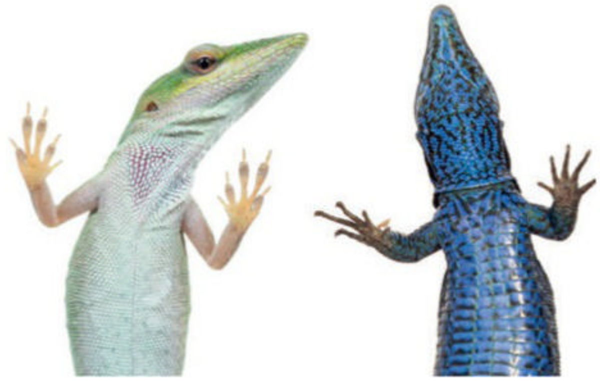
The next step in this research is to find out exactly what lizards with toe pads can do, compared with those which lack this anatomical feature. This is possible by observing the different species in their natural habitat.

"Analysing evolutionary relationships can tell us a lot, but next, we need to go out into nature — to see what parts of the environment that the lizards use and why these evolutionary relationships exist," says Miller.

Further information

Aryeh H Miller, James T Stroud. **Novel Tests of the Key Innovation Hypothesis: Adhesive Toe pads in Arboreal Lizards.** *Systematic Biology*, 2021; DOI: 10.1093/sysbio/syab041

▼ Lizards with sticky toe pads have a greater clinging ability. The tree canopy specialist, the American green anole (*Anolis carolinensis*), pictured on the left, possesses enlarged toe pads, while the terrestrial Ibizan wall lizard (*Podarcis pityusensis*), right, lacks such adhesive structures.
Photos courtesy Day's Edge Productions.



Lizards without toe pads may still be able to climb well - but can they hang on? More field investigations are required.
Photo courtesy Kurit afshen/www.shutterstock.com

Pterosaurs flew from hatching

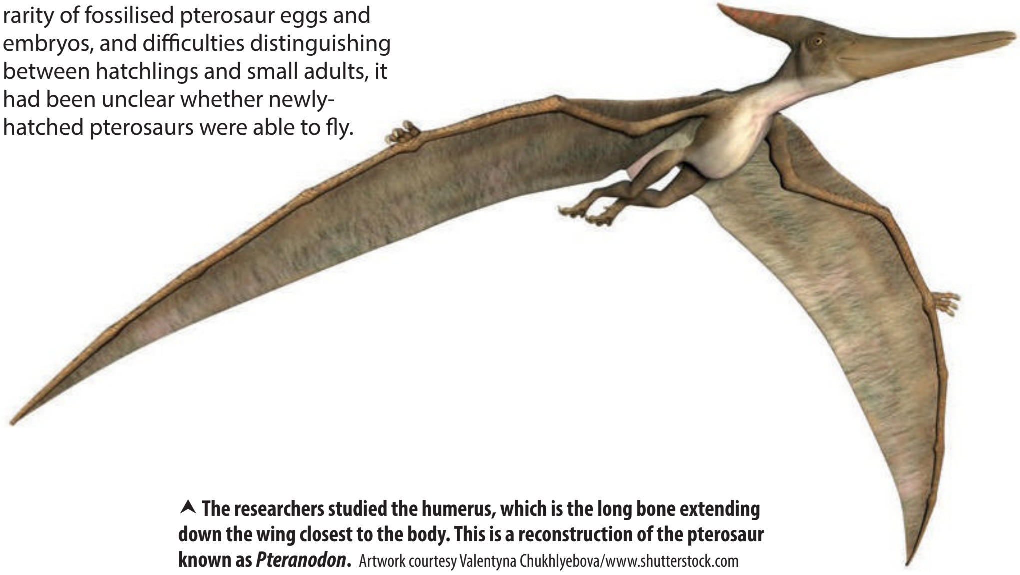
▲ **The aerial mastery of pterosaurs was such that they could fly from hatching, according to a new study.** Artwork courtesy Dariush M/www.shutterstock.com

At least some pterosaurs could take to the air immediately after emerging from the egg, but their flying abilities were probably different when compared with those of adult pterosaurs, based on the findings of a new anatomical study. Pterosaurs were a group of flying reptiles that lived during the Triassic, Jurassic and Cretaceous Periods (extending from 228 to 66 million years ago). Due to the rarity of fossilised pterosaur eggs and embryos, and difficulties distinguishing between hatchlings and small adults, it had been unclear whether newly-hatched pterosaurs were able to fly.

A comparative analysis

Researchers from the universities of Portsmouth and Bristol in the UK, along with palaeontologist Darren Naish, found that humerus bones of hatchlings, (which formed a key part of the wing) were stronger than those of many adult pterosaurs, indicating that they would have allowed the youngsters to fly. As part of the study, the researchers modelled the flying abilities of hatchlings using previously obtained wing measurements from four established hatchling and embryo fossils of two pterosaur species: *Pterodaustro guinazui* and *Sinopterus dongi*.

They also compared these wing measurements with those of adults from the same species, and examined the strength of the humerus in three hatchlings, contrasting the results with those derived from 22 adult pterosaurs. "There's still a lot to learn about the life histories of these animals, but we're confident that, whatever they were doing as they grew up, they were capable of flying from the moment they hatched," says Dr Mark Witton from the University of Portsmouth.



▲ **The researchers studied the humerus, which is the long bone extending down the wing closest to the body. This is a reconstruction of the pterosaur known as *Pteranodon*.** Artwork courtesy Valentyna Chukhlyebova/www.shutterstock.com

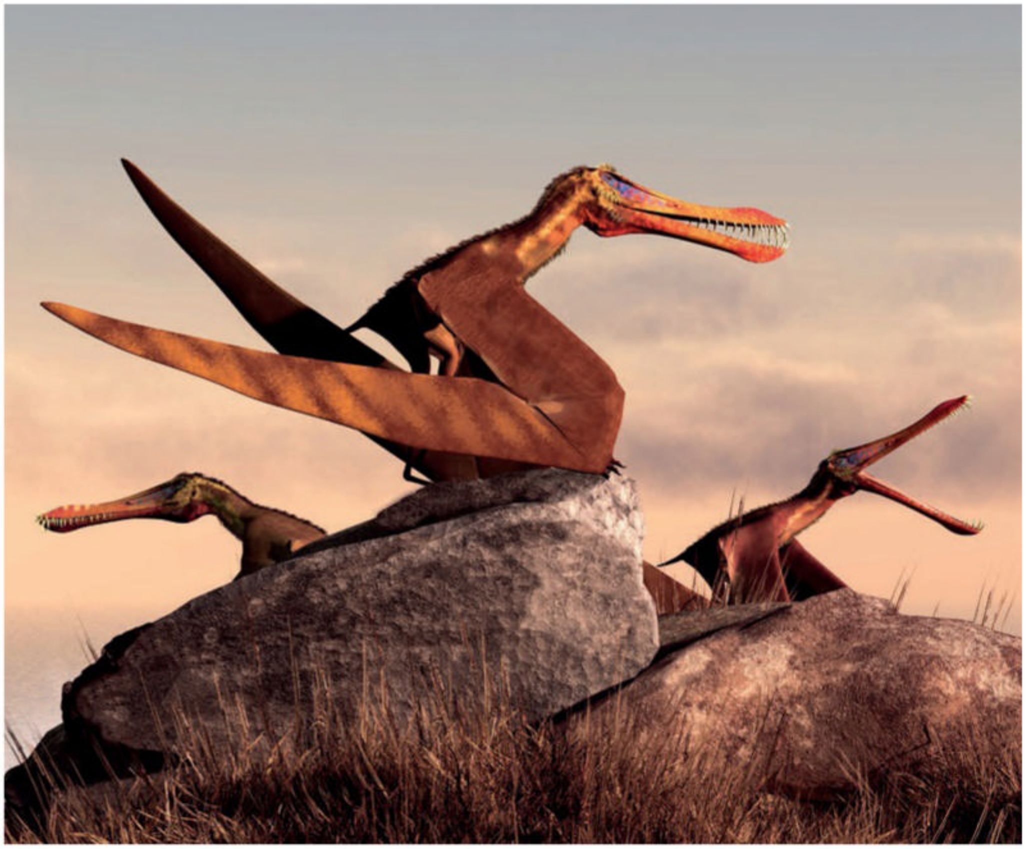
Unlike bats and birds

"Although we've known about pterosaurs for over two centuries, we've only had fossils of their embryos and hatchlings since 2004. We're still trying to understand the early stages of life in these reptiles. One discussion has centred around whether pterosaurs could fly as hatchlings or, like the vast majority of birds and bats, they had to grow a little before they could start flying.

"We found that these tiny animals – with 25cm (10in) wingspans and bodies that could neatly fit in your hand – were very strong, capable fliers. Their bones were strong enough to sustain flapping and take-off, and their wings were ideally shaped for powered (as opposed to gliding) flight," explains Dr Witton.

"However, they would not have flown exactly like their parents simply because they were so much smaller: flight capabilities are strongly influenced by size and mass, and so pterosaur hatchlings, being hundreds of times smaller than their parents, were likely to be slower yet more agile fliers than the wide-ranging but less manoeuvrable adults."

Dr Liz Martin-Silverstone from the University of Bristol's School of Earth Sciences adds: "There have been several debates about whether juvenile pterosaurs could fly, but this is the first time it's been studied from a more biomechanical point of view. It's exciting to discover that even though their wings may have been small, the hatchlings were built in a way that made them strong enough to fly."

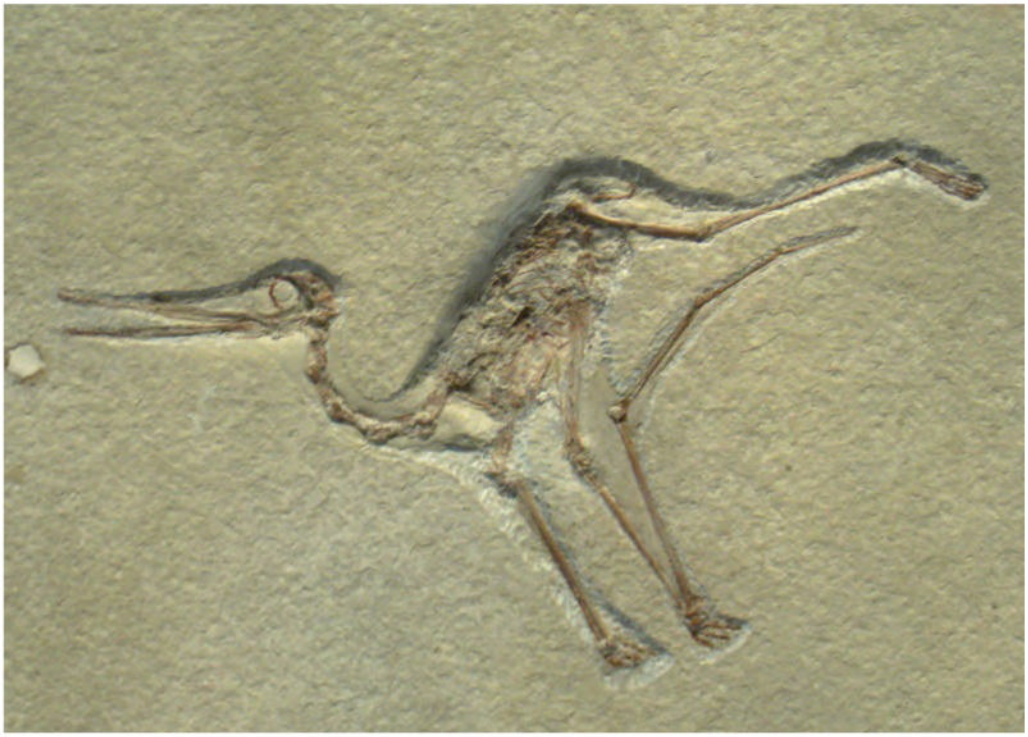


A different lifestyle?

The researchers found that while the youngsters had long, narrow wings, these were shorter and broader than those of adult pterosaurs, with a larger wing area relative to hatchling mass and body size. Their wing dimensions may have made hatchlings less efficient than adult pterosaurs in the air, but could have resulted in them being more agile, enabling them to suddenly change direction and speed.

It is thought that the highly manoeuvrable flying style of hatchling pterosaurs may have enabled them to escape predators more easily. They may also have been better suited to chasing nimbler prey and flying amongst dense vegetation than adult pterosaurs.

"This in turn gives us a lot to think about with regard to flying reptile ecology. How independent were the hatchlings from their parents? Did flight style influence habitat choices, and did these change as pterosaurs grew?" says Dr Witton. "There's still a lot to learn about the fascinating life histories of these animals, but we're now confident that, whatever they were doing as they grew up, they were capable of flying from the moment they hatched."

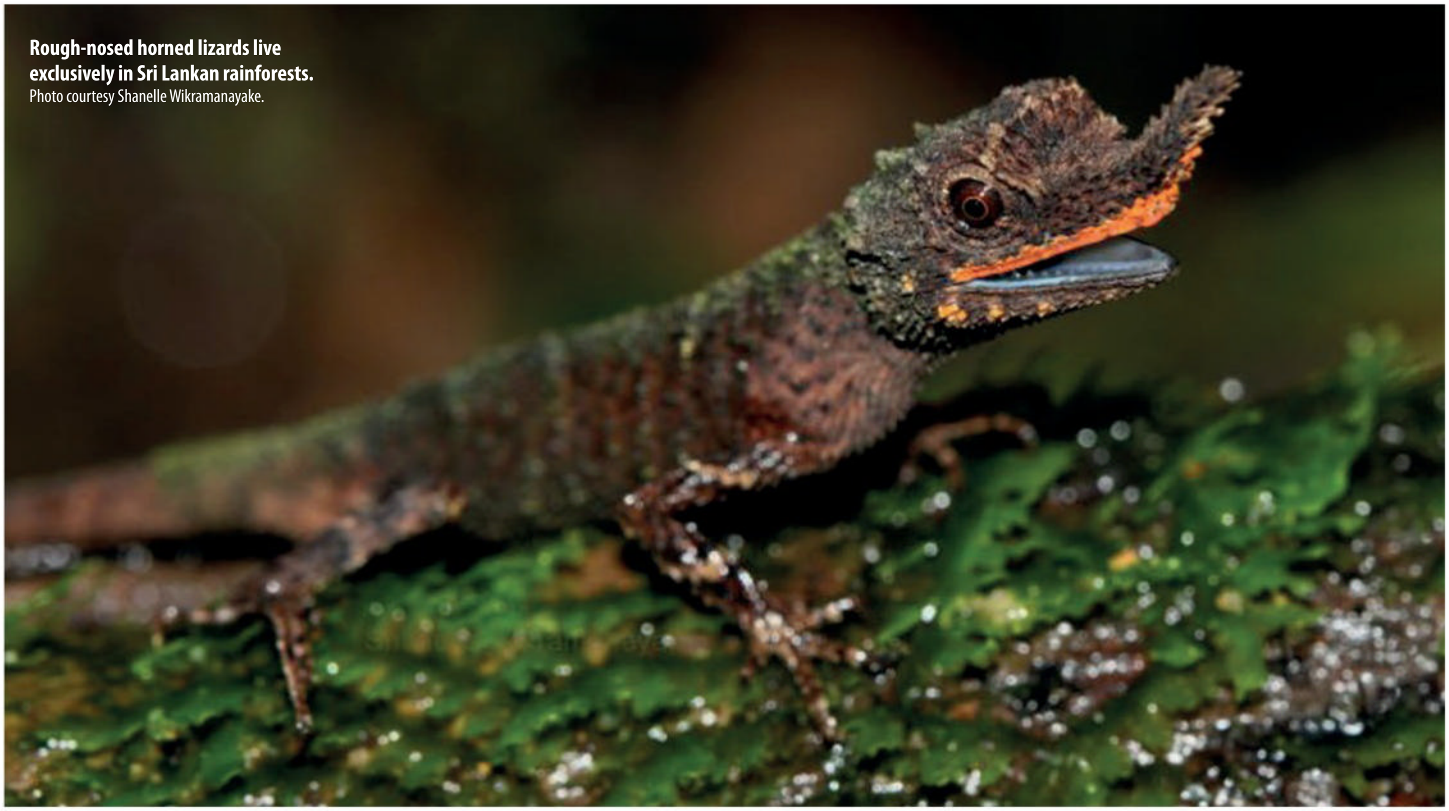


▲ The fossil of a juvenile pterodactyl unearthed in Solnhofen limestone deposits in Germany. This specimen belongs to the species known as *Pterodactylus micronyx*, which is in the collection of the Carnegie Museum of Natural History at Pittsburgh, in the US state of Pennsylvania. Photo courtesy Daderot.

Further information

Darren Naish, Mark P. Witton, Elizabeth Martin-Silverstone. **Powered flight in hatchling pterosaurs: evidence from wing form and bone strength.** *Scientific Reports,* 2021; 11 (1) DOI: 10.1038/s41598-021-92499-z

Critical information for conserving rainforest lizards



Rough-nosed horned lizards live exclusively in Sri Lankan rainforests.
Photo courtesy Shanelle Wikramanayake.

A team of researchers from the University of Washington, the UW Burke Museum of Natural History and Culture, WWF Hong Kong and the University of Colombo has provided an important road map in terms of conserving rough-nosed horned lizards *(Ceratophora aspera)*.

These small lizards live on the island of Sri Lanka, and are not found anywhere else in the world. Characterised by the prominent horn on the nose of males, rough-nosed horned lizards inhabit moist, humid microhabitats in rainforests and palm groves.

This species of lizard is particularly well-suited to illustrate the consequences of rainforest habitat destruction, being found throughout the lowland rainforests in the southwestern part of the island. In addition to habitat destruction and their natural predators which include birds, domesticated species like cats and chickens also eat these lizards, causing further harm to their populations.

▼ The island of Sri Lanka, located to the southeast of India.
Photo courtesy Dmitrijs Kaminskis/www.shutterstock.com

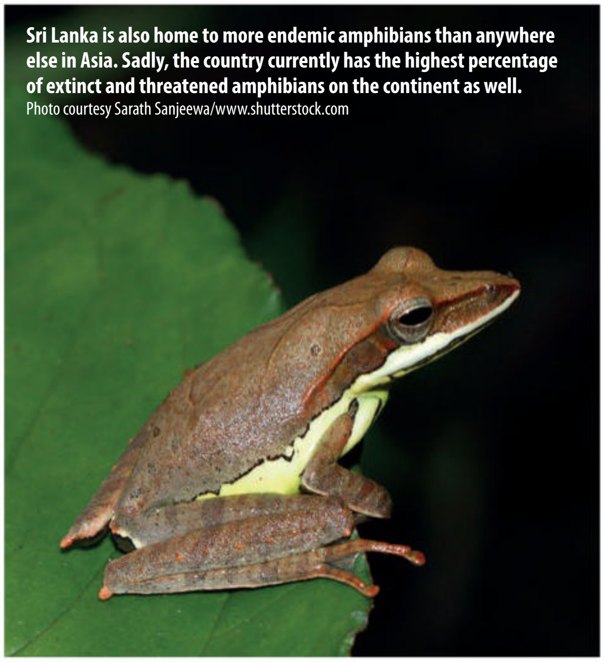
Genetic studies

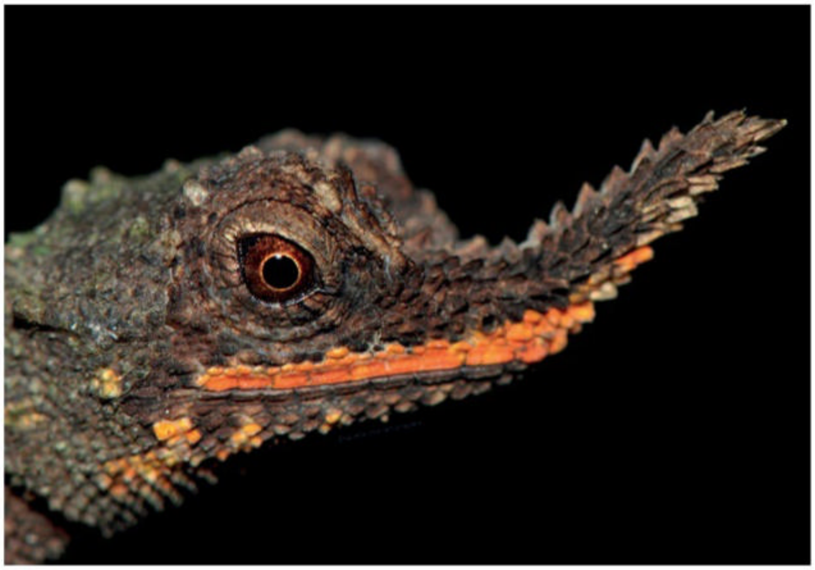
By analysing certain types of mutations in the genome of these lizards, the scientists involved were able to determine how geography and historical events have impacted on the distribution of the surviving wild populations of rough-nosed horned lizards.

The team acquired DNA from the rough-nosed horned lizards by a catch-and-release approach of capturing wild lizards and taking tissue samples from the tips of their tails before releasing them back to the wild, which minimises stress on the reptiles. Samples were taken in eight forests representing four forest groups between July and September.

The remaining tissue samples will be housed along with photos of the

▲ Researcher Shanelle Wikramanayake holds a rough-nosed horned lizard in the field.
Photo courtesy Sanoj Wijayasekara.


Sri Lanka is also home to more endemic amphibians than anywhere else in Asia. Sadly, the country currently has the highest percentage of extinct and threatened amphibians on the continent as well. Photo courtesy Sarath Sanjeewa/www.shutterstock.com


⮝ **Close-up image of a male rough-nosed horned lizard.** Photo courtesy Shanelle Wikramanayake.

lizards at the Department of Zoology and Environment Sciences at the University of Colombo. In addition, the DNA analysis from the team's work is also available online, where the samples and analysis are available for other researchers around the globe to study. The team recommends a conservation strategy that considers the population structure, history and ecology of rough-nosed horned lizards to preserve genetic diversity.

Practical actions

The results from the DNA analysis found rough-nosed horned lizards are separated by distance into four forest groups: Southern Lowlands, Sabaragamuwa Hills, Central Highlands and Kithulgala. With the Sri Lankan government pledging to restore rainforest habitats, the results from the study should help to inform guidelines for forest landscape restoration.

For example, the similarities in populations and close geographic proximity between the lizards living in the Hiyare and Kottawa forest reserves in the Southern Lowlands forest group means this area is an ideal candidate for habitat restoration. The two populations could be reconnected, increasing the chances for interbreeding, which should result in a stronger gene pool for future generations, leaving them less vulnerable to extinction.

Looking to the future

"I hope this study brings attention to the unique and little-known biodiversity present in the rainforests of Sri Lanka that requires urgent conservation action," says Shanelle Wikramanayake. "It's important to consider the genetic diversity in populations across the range of this species when looking at conservation planning and strategies. This principle should also be considered in other forest ecosystems, where conservationists are planning restoration of the environment and habitat connectivity."

In addition to these lizards, the researchers are currently considering extending this work to other animals and more regions of Sri Lanka that are of high conservation value. A significant number of the species found on the island are endemic. Approximately 14% of mammals, 6.5% of birds, 75% of reptiles and 29% of flowering plant species are only present there. The methods of DNA analysis used in this study will not only assist conservation planning in Sri Lanka, but also, they can be applied to species living in other rainforests that are at risk, including those on Madagascar, Borneo and in the Amazon."

⮟ **Sanoj Wijayasekara (left) and Shanelle Wikramanayake (right) examine and take a tissue sample from a rough-nosed horned lizard.** Photo courtesy Shanelle Wikramanayake.

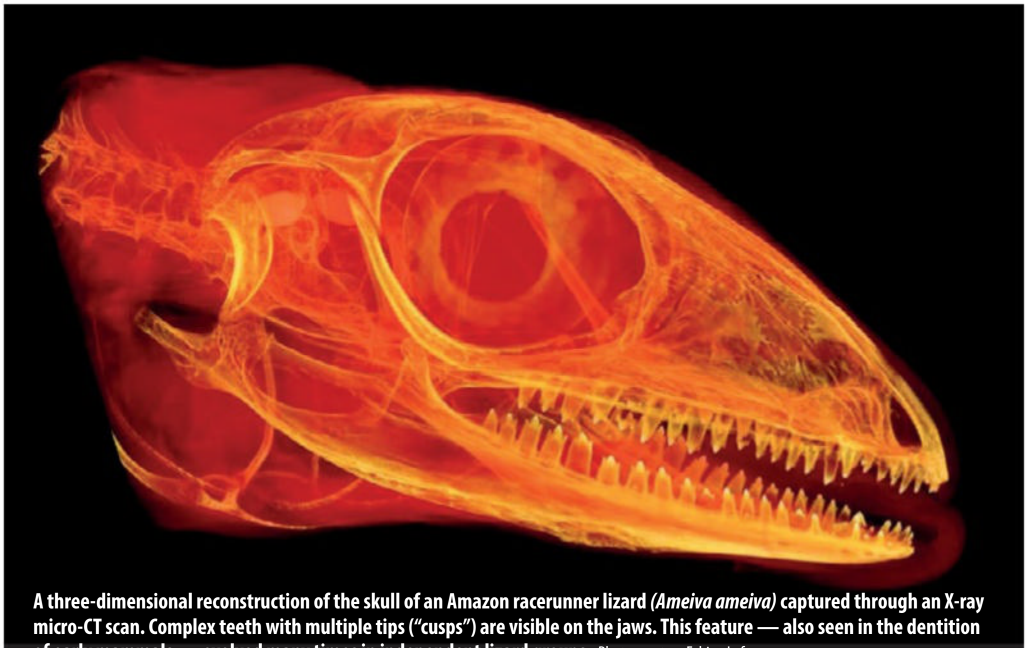
Further information

Shanelle A. Wikramanayake, Eric D. Wikramanayake, Nirmalie Pallewatta, Adam D. Leach. **Integration of genetic structure into conservation of an endangered, endemic lizard, *Ceratophora aspera*. A case study from Sri Lanka.** *Biotropica*, 2021; DOI: 10.1111/btp.12970

At the cusp of dental evolution

Researchers at the Universities of Helsinki and Lyon and the Geological Survey of Finland have found that complex teeth, which are a hallmark of mammals, have also evolved several times in reptiles, prompting the evolutionary success of plant-eating lizards. However, contrary to the situation in mammals, their tooth evolution was not unidirectional.

The new study reveals that several lizard groups evolved teeth with multiple tips (called "cusps") that allowed them to exploit new plant-based diets and enabled new species to evolve more quickly. Surprisingly, tooth evolution was more flexible in lizards and snakes than mammals, expanding our view of dental and dietary evolutionary links in vertebrates.



A three-dimensional reconstruction of the skull of an Amazon racerunner lizard *(Ameiva ameiva)* captured through an X-ray micro-CT scan. Complex teeth with multiple tips ("cusps") are visible on the jaws. This feature — also seen in the dentition of early mammals — evolved many times in independent lizard groups. Photo courtesy Fabien Lafuma.

Tooth shape linked to diet

Scientists have previously documented the connection of tooth shape and diet in mammals in detail, showing that a very diverse dentition fuelled their evolutionary success. But what about other toothed animals, such as squamates, the group of reptiles incorporating lizards and snakes? "The teeth of squamates have not been studied in such detail, even though they outnumber the number of mammalian species twofold and occur in many habitats and geographic ranges," says Nicolas Di-Poï who is Associate Professor at the Institute of Biotechnology, University of Helsinki.

Teeth in the mouth of a blue-eyed anglehead lizard *(Gonocephalus liogaster).* Photo courtesy Chattraphas Pongcharoen/www.shutterstock.com

The researchers performed comparative analyses on tooth shape and dietary data for more than 500 living and fossil species of squamate. They found the ancestor of all snakes and lizards had simple peg-like teeth and fed on insects. Later, complex teeth bearing multiple cusps — similar to those of early mammals — evolved independently many times in different lizard lineages. The appearance of multiple-cusped teeth allowed some lizard groups to progress to eating more plant-rich diets, and sometimes led to even more complex teeth.

Lizards' teeth evolution took two directions

The team also found that complex teeth and plant consumption provided an evolutionary advantage, as both traits favoured the appearance of new species. However, many lizard lineages also lost complex teeth to re-evolve the simple tooth morphology of their ancestors. "This came as a complete surprise," admits Fabien Lafuma, who is also based at the University of Helsinki. "Complex teeth appear to be a critical innovation for both squamates and mammals."

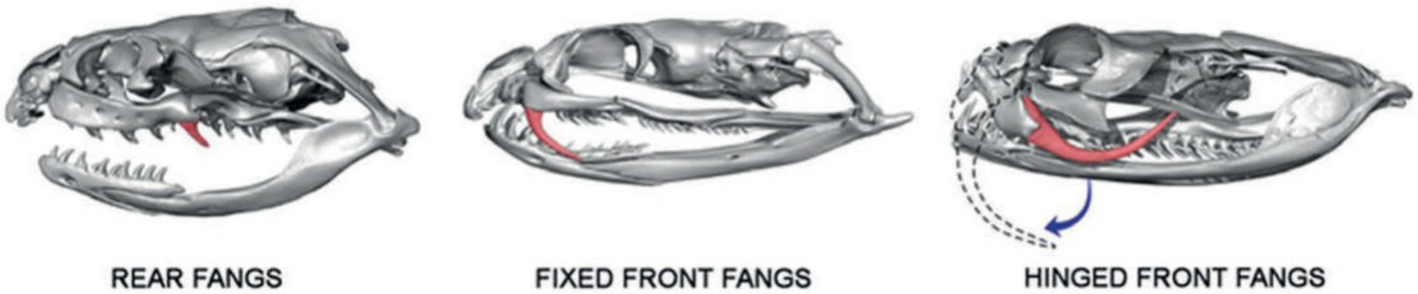
The study suggests that all land-living vertebrates experience the same selective pressures for more cusps to increase plant consumption. Nevertheless, fundamental differences make squamates stand out. Contrary to mammals, tooth evolution was not unidirectional, and numerous lineages reduced complexity over time.

This difference could stem from variations in tooth development, showing that minor molecular changes may produce widely different outcomes over evolutionary time scales. This work gives us a more nuanced understanding of how the same critical adaptation evolved in different vertebrate groups," concludes Lafuma.

Further information

Lafuma, F., Corfe, I.J., Clavel, J., and Di-Poï, N. **Multiple evolutionary origins and losses of tooth complexity in squamates.** *Nature Communications,* DOI : 10.1038/s41467-021-26285-w

How snakes got their fangs



⮝ Types of venom fangs in snakes: rear fangs (crab-eating water snake); fixed front fangs (taipan) and hinged front fangs (Gaboon viper), with the fangs being highlighted in red. Image courtesy A. Palci/Creative Commons CC0.

Have you ever wondered how deadly snakes evolved their fangs? The answer lies in particular microscopic features of their teeth, according to research led by Flinders University and the South Australian Museum. "It's always been a mystery why fangs have evolved so many times in snakes, but rarely in other reptiles. Our study answers this, showing how easy it is for normal snake teeth to turn into hypodermic needles," explains Dr Alessandro Palci from Flinders University.

Different designs

Out of a total of almost 4,000 recognised species of snakes alive today, about 600 of them are considered 'medically significant' to humans, meaning that if you get bitten you are very likely to require an urgent visit to the nearest hospital for treatment. Venom fangs are modified teeth that are grooved and larger than other nearby teeth. They can be located at the back or at the front of the mouth, where they can be fixed or hinged (meaning that they can fold backwards).

The researchers used high-tech modelling, fossils, and hours of microscopic observations to reveal that snakes possess tiny infoldings, or wrinkles, at the base of their teeth. These infoldings might help teeth attach more firmly to the jaw. In venomous snakes, one of these wrinkles becomes deeper and extends all the way to the tooth tip, thus producing a venom groove and a fang.

"Our work also highlights the opportunism and efficiency of evolution. Wrinkles which helped attach teeth to the jaw were repurposed to facilitate the injection of venom," adds Michael Lee, Matthew Flinders Professor at Flinders University.

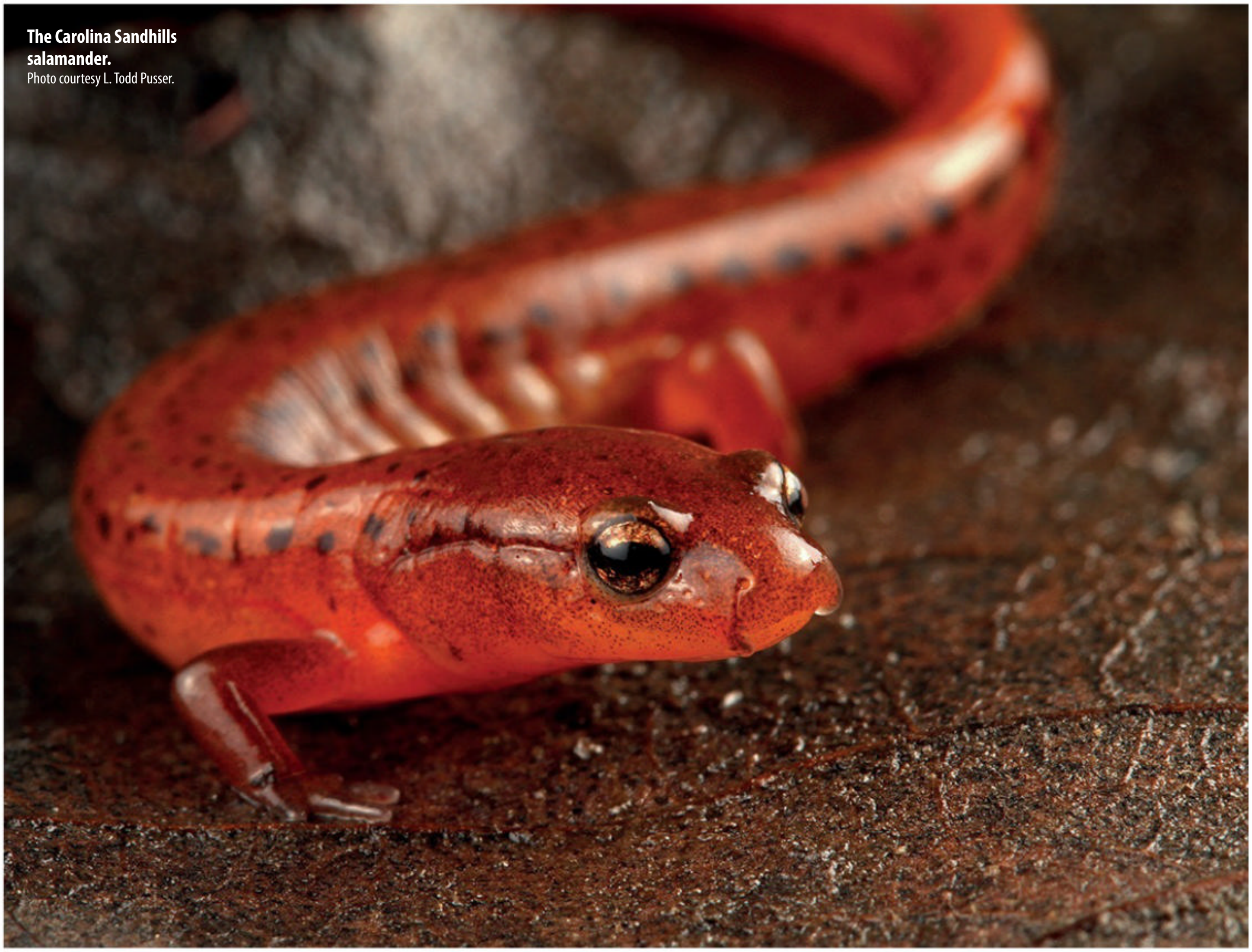
The teeth and fangs in the jaw of a cobra. Photo courtesy PUMPZA/www.shutterstock.com

A rattlesnake with drops of venom evident on its fangs. Photo courtesy Maria Dryfhout/www.shutterstock.com

Further information

Alessandro Palci, Aaron RH LeBlanc, Olga Panagiotopoulou, Silke GC Cleuren, Hyab Mehari Abraha, Mark N Hutchinson, Alistair R Evans, Michael W Caldwell and Michael SY Lee (2021). **Plicidentine and the repeated origins of snake venom fangs.** *Proceedings of the Royal Society* B 288: 20211391. https://doi.org/10.1098/rspb.2021.1391

New salamander discovered



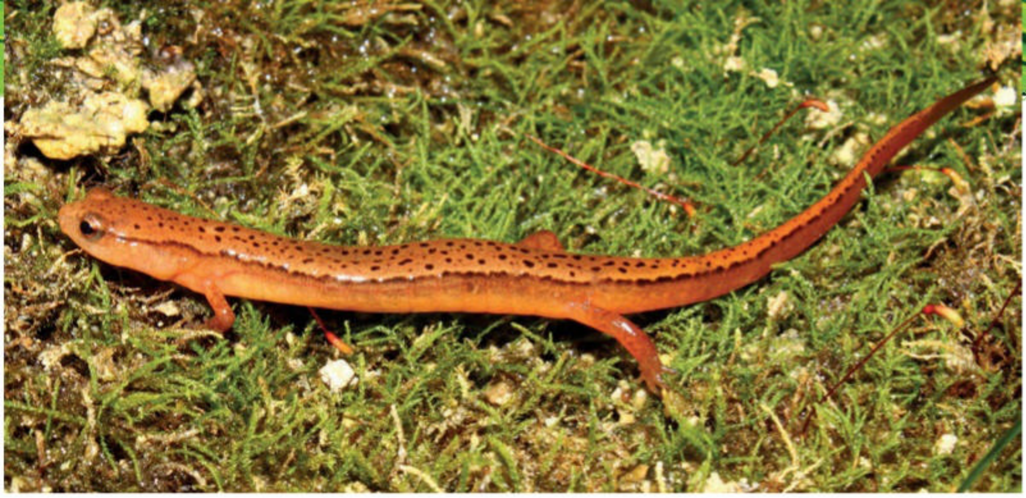
The Carolina Sandhills salamander.
Photo courtesy L. Todd Pusser.

Already possessing more salamander species than any other state in the US with 63, North Carolina has just added one more to its total. The aptly-named Carolina Sandhills salamander *(Eurycea arenicola)* is found in association with springs, seepages and small blackwater streams in the Sandhills region of North Carolina.

This new species of salamander was previously regarded as an aberrant population of the southern two-lined salamander *(Eurycea cirrigera),* but researchers at the North Carolina (NC) Museum of Natural Sciences applied next generation DNA sequencing technology to show that the new species differs genetically (in both the mitochondrial and nuclear genome)

Northern two-lined salamanders display the stripes running along their bodies.
Photo courtesy Joe McDonald/ www.shutterstock.com

from other species of two-lined salamanders forming the *Eurycea bislineata* complex). These results back up more obvious evidence, as the Carolina Sandhills salamander also differs in colouration, size and natural history from other members of the complex.



⮝ **The southern two-lined salamander (*Eurycea cirrigera*) with which the new species was confused. Both are endemic to North Carolina Sandhills region.**
Photo courtesy Jason Patrick Ross/www.shutterstock.com

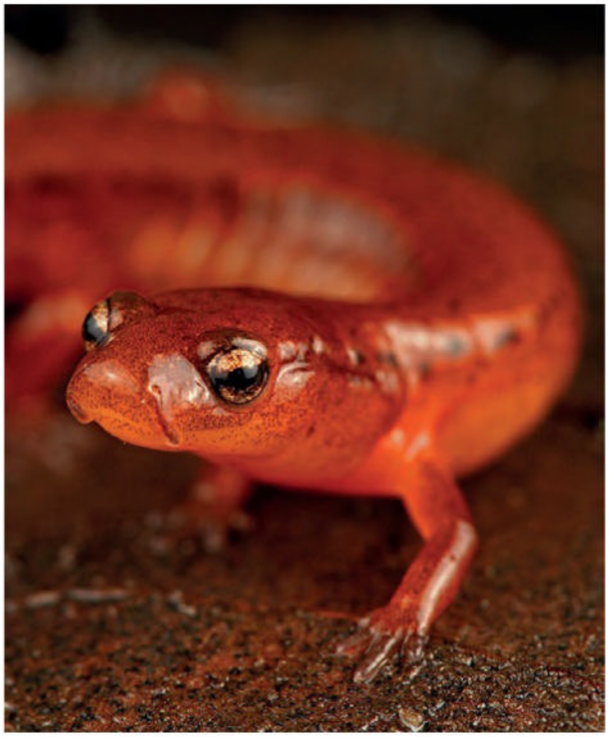
A long time coming…

It's a discovery 50 years in the making. The first specimen of the new species was collected and identified in October 1969 and brought to the attention of the NC Museum's Alvin Braswell, then the assistant curator for lower invertebrates and now just recently retired. At first, Braswell thought that this original specimen was simply a weird individual of *Eurycea cirrigera,* but then in the mid-1970s, he started finding additional "weird individuals" and thought maybe there's something more to this!

As it turned out, the original specimen had been misidentified. Among other things, *Eurycea arenicola* is smaller on average in size, and mature individuals have a pronounced reddish colour. "It's a real neat critter," Braswell says.

A unique habitat

The fact that its range is restricted to the Sandhills is also unique. The Sandhills, according to Braswell, is an area that comprises the "best of what's left in North Carolina" in terms of the once extensive Longleaf Pine ecosystem, which originally stretched from southeast Virginia all the way south to Florida. So much of that ecosystem — roughly 95 percent in total — has been altered or lost through development and conversion to other land use practices, but the NC Sandhills includes extensive Game Lands and Fort Bragg, protecting some very important habitat. The name itself reflects the species' tie to the Sandhills, as *arenicola* means "dweller of a sandy place".



⮟ **Deep red colouration and a small size help to distinguish the new salamander visually, although genetic separation was key to its identification.**
Photo courtesy L. Todd Pusser.

The breakthrough

During the 1980s, Braswell began the process of describing the new species but never completed it. Burdened with administrative duties, he ultimately turned it over to Bryan Stuart, who joined the NC Museum as research curator of herpetology in 2008, imploring him to "take it and run with it."

Finally, during 2013, Stuart received a National Science Foundation Research Opportunity Award (ROA) that enabled detailed genetic research using a new, next generation sequencer. "With that machine, we were able to sequence a sufficiently large number of genes to test the distinct species status of the Carolina Sandhills salamander," says Stuart.

Carolina Sandhills salamander specimens were located and collected in Harnett, Hoke, Montgomery, Moore, Richmond, Robeson and Scotland counties. "Almost every known specimen of the new species is housed in our collection, with just a handful of individuals at a few other museums," notes Jeff Beane, collections manager for herpetology at the NC Museum. "No records are yet known from South Carolina, but we have a record in North Carolina that is only two miles from the state line, so it gets close."

Pittsburgh
Baltimore
Annapolis
Dover
Washington
WEST VIRGINIA
VIRGINIA
Charleston
Richmond
Norfolk
Greensboro
Raleigh
Winston-Salem
NORTH CAROLINA
Charlotte
Greenville
Columbia
SOUTH CAROLINA
Charleston
Atlanta
95
85
40

⮝ **North Carolina has now moved to offer some protection to the new salamander.**
Photo courtesy klenger/www.shutterstock.com

Further insights

Despite being officially unnamed until this paper came out, the small geographic range of the Carolina Sandhills salamander has prompted it to be listed on the W3 Watch List by the North Carolina Natural Heritage Program – meaning it is a "species that is poorly known and perhaps needs listing in upcoming years."

"This research also reveals that there are other undescribed species in this complex that await description, even some that occur in North Carolina," Stuart adds. "So there is definitely more to do with two-lined salamanders in the state."

Further information

Bryan L. Stuart, David A. Beamer, Heather L. Farrington, Jeffrey C. Beane, Danielle L. Chek, L. Todd Pusser, Hannah E. Som, David L. Stephan, David M. Sever, Alvin L. Braswell. **A New Two-Lined Salamander (*Eurycea bislineata* Complex) from the Sandhills of North Carolina**. *Herpetologica*, 2020; 76 (4) DOI: 10.1655/0018-0831-76.4.423

People's perceptions of rattlesnakes investigated in a collaborative study

Arizona is a state where conditions are ideal for many reptiles, including snakes. Photo courtesy Set Lane/www.shutterstock.com

Arizona! The sunsets. The saguaros. Ah yes - and the snakes! All of them are part of life in this sunny part of the southwestern USA, but keeping cool when the latter is holed up in a golf bag, air compressor or swimming pool might seem a big ask for many people. However, the first study to analyse snake removals in a social-ecological context was recently published by a Arizona State University conservation biologist working with a local rattlesnake removal company, and yielded surprising results.

"I think the most significant finding overall was that people don't hate snakes," explains researcher Heather Bateman of the College of Integrative Sciences and Arts. "A lot of them responded that the snakes are important to the desert ecosystem and the snake belongs in the desert, just not in my garage for example."

Where the issues are greatest

Snakes were most frequently removed from neighbourhoods with wealthier and more highly educated residents, a greater proportion of Hispanic residents and recently constructed homes.

➤ **Many of Bryan Hughes's call-outs are north of the Loop 101 freeway. The McDowell Mountains of Scottsdale can be seen in the distance.** Photo courtesy Tim Roberts Photography/www.shutterstock.com

son City
BASIN
4
70
Las Vegas
15
River
sfield
40
Flagstaff
ARIZONA
San Bernardino
Colorado
10
Phoenix
Tucson

➤ **Arizona is located in the southwestern part of the USA, adjoining the border with Mexico.** Photo courtesy klenger/www.shutterstock.com

Bateman studied the records of 2,000 snake removals in metro Phoenix between 2018 and 2019. More than 68% of removals were of the venomous western diamondback rattlesnake *(Crotalus atrox),* which is the most common species in the area. The contact zone for rattlesnakes and other species tends to be on the Valley fringes, according to Bryan Hughes, owner of Rattlesnake Solutions. He gets the most calls from north of the Loop 101 freeway in Phoenix, Scottsdale and Cave Creek.

"A lot of that (area) has this very deep penetration zone where you can find rattlesnakes miles into areas that have been developed," Hughes explains. "And that's just because of the way that the properties are developed. They leave natural waterways in place and tend to use xeric (dry) landscaping on larger lots."

Rattlesnakes also turn up in Phoenix around the mountain preserves. "That contact zone is razor-thin," he adds. "It's basically just that first row of houses that surround those parks."

Snake removal was high in neighbourhoods with a high income. But in high-income and high-education areas, snake removal was lower. "That might indicate that there is an understanding that snakes play these important roles in ecosystems and maybe they're okay to be left in place or handled a different way," Bateman suggests. "Maybe it's because they understand the positive benefits of snakes in terms of rodent control perhaps, and so are less concerned and maybe decide against removal."

Snakes rarely get inside houses, but if they do, they come in through an open door, according to Hughes. "We do have a lot of people that move here from cooler areas where a nice spring day means you leave the back patio unlocked and open a little bit, and rattlesnakes will come in there occasionally that way, but very rarely," he explains. "Most of the time when we get snakes at people's houses, it's in the backyard or the front yard where a lot of the landscaping is something that can be useful or mimics in some ways the native landscaping that the snakes use."

A unique resource

Hughes grew up in Idaho catching snakes for fun. He moved to Arizona 22 years ago. "My interest in snakes changed from garter snakes to rattlesnakes at that point," he says. His snake removal business has been operating for about 10 years now. He has about 25 employees positioned around the Valley and Tucson, who can usually show up for a call in half an hour. "We have a massive data set just because we're out there and able to collect a lot of information," he adds. "So I'm really excited about this type of collaboration."

Equally, the amount of data Hughes had on hand was a delight to Bateman. "There's a lot that ecologists can gain and by partnering with the business community," she says. "What a great relationship to pair scientists with this business which also is using science. They understand their snakes. And they're contributing to what we know just about the natural history of these species. ...

"If I look at other sources of information of snakes in Maricopa County, I can go to the scientific literature and there's a couple of papers. And they studied snakes for years. They used road writing surveys (where biologists walk or drive down roads and record what they find) and other types of surveys. And they found hundreds of snakes, not the thousands of snakes that Brian and his staff have recorded."

⮝ Over two-thirds of the call-outs involved the western diamondback rattlesnake *(Crotalus atrox)*. Photo courtesy Ryan M. Bolton/www.shutterstock.com

➤ A roadrunner poised to strike at a western diamondback rattlesnake in Arizona. This ground cuckoo is a natural predator of these snakes, and will also hunt other reptiles. Photo courtesy Danita Delimont/www.shutterstock.com

⮟ Rattlesnake removal in progress in Arizona. Photo courtesy Grossinger/www.shutterstock.com

Practical applications

The published study will be of use to Hughes in his work as well. "One of the biggest things that is going to be beneficial for me just dealing with the public is the fact that how people felt about snakes was not meaningfully impacted by whether or not it's an area where a lot of snakes are removed," he explains.

"I've always believed that our culture has a lot to do with whether or not people feel positively or negatively about snakes. And much of what's in there suggests that too, which gives me a lot of lessons about how, when I'm talking to somebody that is scared of snakes, I can best communicate with them and possibly be able to change their mind about these reptiles."

Further information

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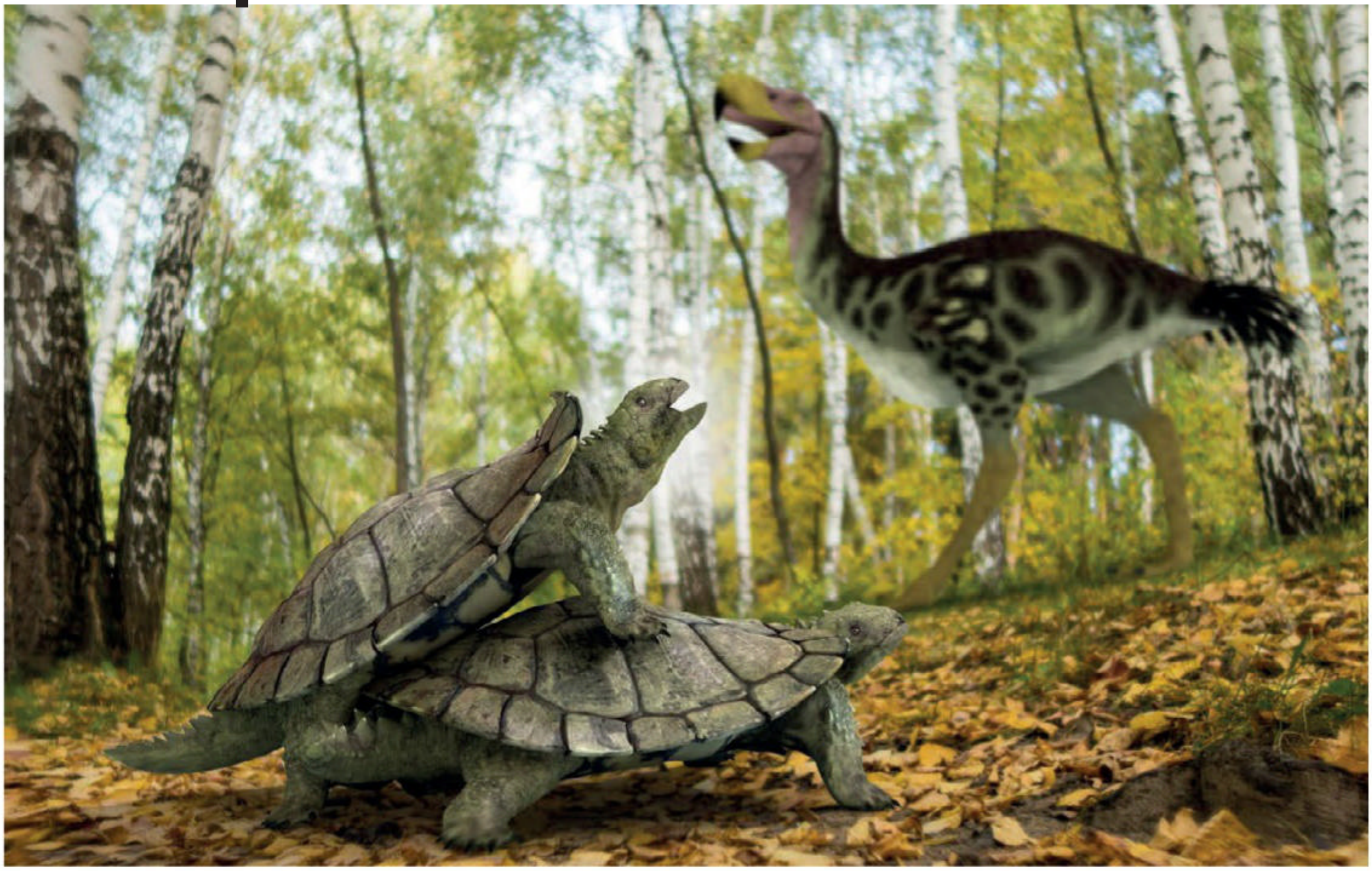
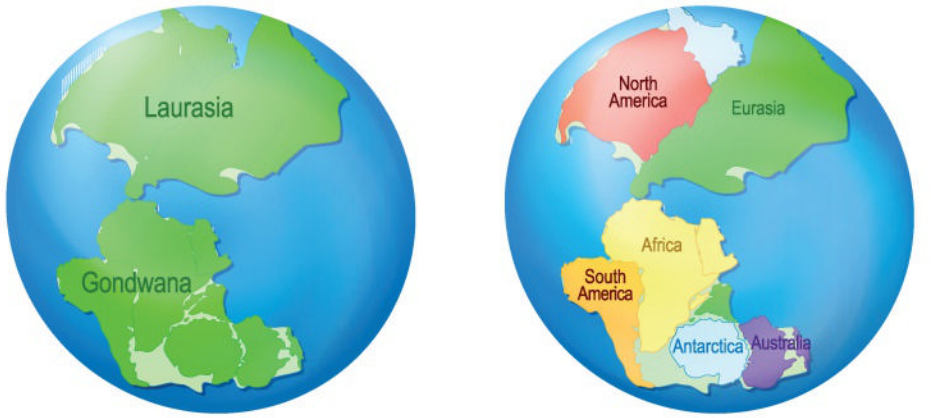
A single turtle survived the northern hemisphere's mass extinction



⮝ A reconstruction of *Laurasichersis relicta*. Artwork courtesy José Antonio Peñas (SINC).

One single primitive turtle resisted a mass extinction event approximately 66 million years ago, in the area called of Laurasia - now the northern hemisphere. This individual managed to survive the event that killed the dinosaurs. It was the only one to do so in this area of the world, according to a Spanish palaeontologist who has analysed its peculiar fossilised remains, found in France.

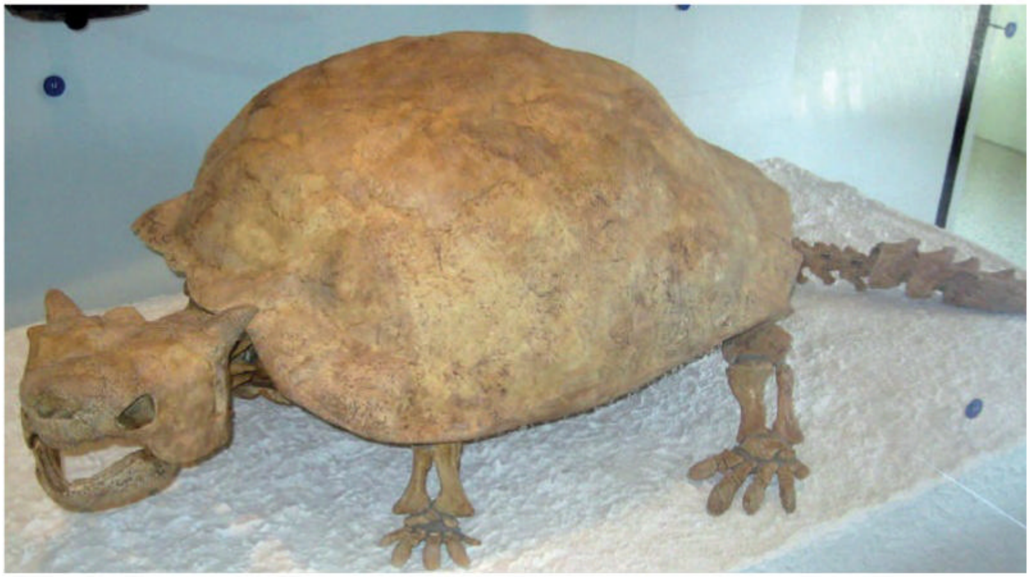
At that stage when the asteroid struck, there were just two supercontinents. Map courtesy Designua/www.shutterstock.com



An evolutionary bottleneck

All turtle species we know of today are descendants of two lineages that separated during the Jurassic, more than 160 million years ago. But their members were not the only ones that existed. There had been many groups of primitive turtles before them, in previous evolutionary periods. Some of these ancient reptiles lived at a time when dinosaurs dominated the Earth. However, virtually all of the early groups of turtles disappeared after an asteroid impact that took place 66 million years and wiped out 70% of life on the planet.

Only the so-called "horned turtles" or meiolaniids managed to hold out, more specifically in Gondwana, the current southern hemisphere, according to fossils found in Oceania and South America. Their last representatives managed to co-exist until relatively recently with humans, who hunted them to extinction. No



The fossilised remains of a meiolaniid in the collection of the American Museum of Natural History. Note the bony projections at the back of the skull, which would have looked like horns. These chelonians were restricted to southern latitudes. Photo Claire Houck from New York City, USA. CC BY-SA 2.0.

other primitive turtle had previously appeared in the records of the last 66 million years.

After a decade of study however, palaeontologist Adán Pérez García, from the Evolutionary Biology Group of the National University of Distance Education (UNED, Spain), now confirms that, in the northern hemisphere, *Laurasichersis relicta* also survived through this tumultuous period in the Earth's history. Its lineage had evolved independently from that of the Gondwana tortoises, after separating from them 100 million years earlier.

"The reason why *Laurasichersis* survived the great extinction, while none of the other primitive North American, European or Asian land turtles managed to do so, as far as we know, still remains a mystery however," admits Pérez García.

A drastic change after extinction

The impact of the asteroid plunged the Earth into a spiral of gas emissions, molten material and acid rain that caused a sudden warming of the climate and dramatically transformed the landscapes in which the turtles lived. "The fauna of European turtles underwent a radical change: the forms that inhabited this continent before the extinction disappeared, and their role in many ecosystems was left vacant until the relatively rapid arrival of new groups from various places in North America, Africa and Asia," Pérez García says.

All of those identified in these new ecosystems seem to belong to the two lineages that have persisted to this day, but the new study allows us to recognise that they were not alone. The appearance in a site in northeastern France of fossils of the shell, limbs and skull of *Laurasichersis relicta* reveals that this primitive species also survived the mass extinction event in Laurasia.

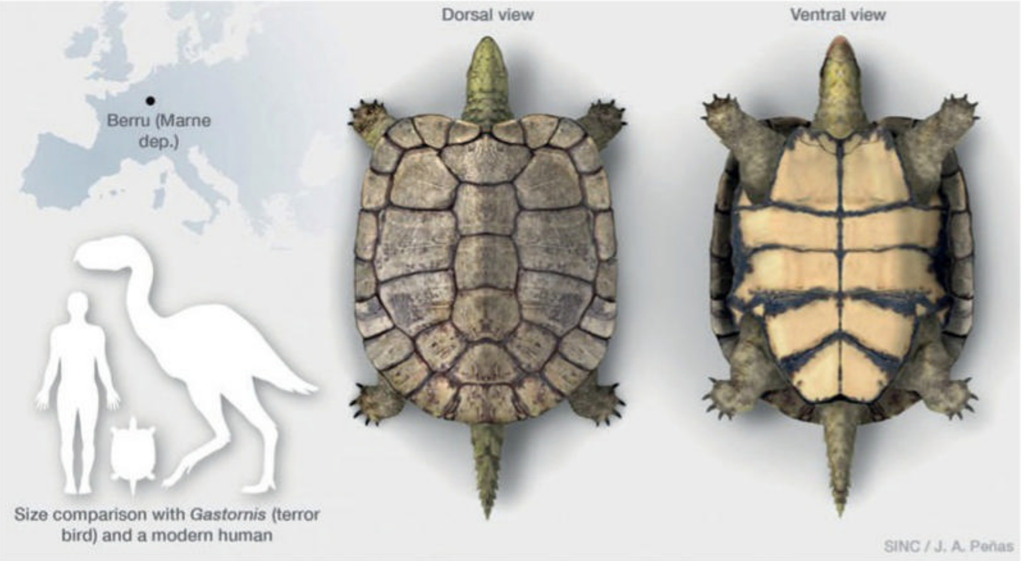
However, its origin stems from another continent: "It is the last representative of a group previously identified in China and Mongolia, where it had occurred since the Jurassic, more than 100 million years before the European *Laurasichersis* turtle existed," says José Antonio Peñas.

A special turtle

The shell of the newly discovered turtle was just over 60cm (24in) long as an adult and, like other primitive reptiles, it could not retract its neck into its shell to conceal its head from predators. This physical limitation meant that it developed other protective mechanisms such as an armour with large, mutually linked spikes, which were hard structures located on the neck, legs and tail.

Its peculiar shell is one of the most remarkable features of this reptile and one of the characteristics that make it unique. This complex structure was made up of numerous plates. "Although the number of plates is usually the same in most turtles, the ventral shell region of the new species was provided with a greater number of these elements than those known in any other turtle," Pérez García stresses.

After the meteorite with its 10km (6ml) diameter hit the Earth, the large dinosaurs ceased to be part of the landscape, but the turtle, which lived in humid environments with forest areas, coexisted with new predators. The latter quickly dominated the positions of the food chain that had remained available when most animals disappeared, and subsequently, *Laurasichersis relicta* vanished at some stage from this new world.


Dorsal view
Ventral view
Berru (Marne dep.)
Size comparison with *Gastornis* (terror bird) and a modern human
SINC / J. A. Peñas

The area of France today where the turtle's remains were unearthed, and a reconstruction of its appearance. Artwork courtesy José Antonio Peñas (SINC).

Further information

Adan Perez Garcia. **Surviving the Cretaceous paleogene mass extinction event: A terrestrial stem turtle in the cenozoic of Laurasia.** *Scientific Reports* January 30th 2020.

Earlier springs can adversely affect amphibians

Wood frog tadpole. Photo courtesy Jessica Hua.

Driven by climate change, spring in the northeastern United States is now earlier and more variable in temperature than it used to be, and this shift has rippled through ecosystems. Among the most severely affected are spring-breeding amphibians such as wood frogs *(Lithobates sylvaticus),* which may be lured out of the mud where they have been hibernating to mate too early. When winter comes rushing back in, although the adult wood frogs will be likely to survive the chill, their newly laid eggs may be at risk. Unfortunately the impact doesn't end there either, according to new research by Binghamton University's Department of Biological Sciences.

Later broods of hatchlings whose parents endure freezing temperatures associated with an additional winter storm are larger but less resilient to the effects of road salt, which is a common wetland pollutant, according to this new research. It focuses on several populations of wood frogs located about a 4½ hour drive southwest from Binghamton, which typically start breeding anytime between mid-March and mid-April.

It also addresses a common but sometimes overlooked environmental pollutant: salt. Every winter, a staggering 10 million metric tonnes (11 million tons) of road salt are applied to North American roadways, washing off in the melting snow and spring rain. This run-off can easily increase the salinity of nearby wetlands and prove toxic to freshwater species such as amphibians.

Amphibians of course are an essential component of wetland ecosystems, and harmful effects on their populations can have widespread effects through the ecosystem and beyond. In addition, as tadpoles, amphibians feed on algae, increasing water clarity and quality of wetlands. Tadpoles additionally serve as prey to many species of aquatic creature, making them important contributors to the cycling of nutrients within wetland ecosystems.

Early mating does not lead to improved breeding success - quite the reverse. Photo courtesy Mark Mierzejewski/www.shutterstock.com

A wood frog in frozen surroundings.
Photo courtesy Jess Lang/www.shutterstock.com

Early spring and offspring

A combination of factors spur amphibians to mate, often hinging on both temperature and the timing of spring rain, researcher Jessica Hua explains. For wood frogs in particular, scientists predict their breeding time by the absence of ice on the pond, a string of three to four days above freezing, and rain during those days.

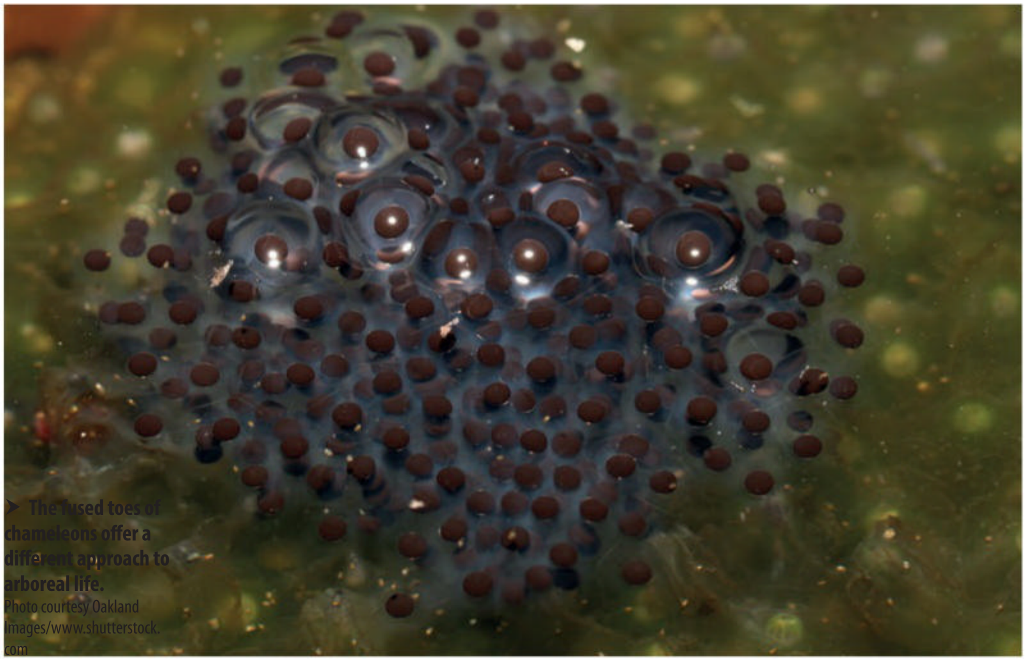
While amphibians are cold-blooded, warmer weather isn't necessarily better. They evolved their breeding schedules over thousands of years in response to environmental cues, Hua's colleague Lindsey Swierk explains. In comparison, climate changes over the last few decades have been rapid, testing the limits of these species' ability to cope.

"Our results suggest that the effects of climate change on wood frog breeding are complex, depending on the severity of freezing events from year to year, and are interactive with other human-introduced stressors like contaminants," she says.

"Though each wood frog female can lay over 500 eggs, many of these eggs may be vulnerable if the pond freezes over," Hua explains. The embryos, too, are hit hard by sudden cold. In a previous study, the researchers exposed frog embryos to cold conditions and found that they took longer to develop into tadpoles, weighed less after hatching and were less tolerant of road salt than embryos raised in warmer environments.

In this case, the researchers removed the eggs from the environment in which they were laid and raised them in the lab. They found that eggs laid later in the mating season by parents who were exposed to an additional winter storm were less likely to withstand salt pollution. The researchers suspect that earlier-breeding frogs were exposed to less temperature-induced stress than those that bred later. This may have translated into less physiological stress and a greater ability for those early breeders to acclimatise to increased salt in the environment.

While stress hormones can allow animals to survive when faced with temporary adverse conditions, prolonged or severe exposure to stressors can cause those same hormones to have ill effects, according to Swierk. "Chronically elevated stress hormones can have cascading impacts on other hormones, such as those related to homeostasis, growth or reproduction," she explains.

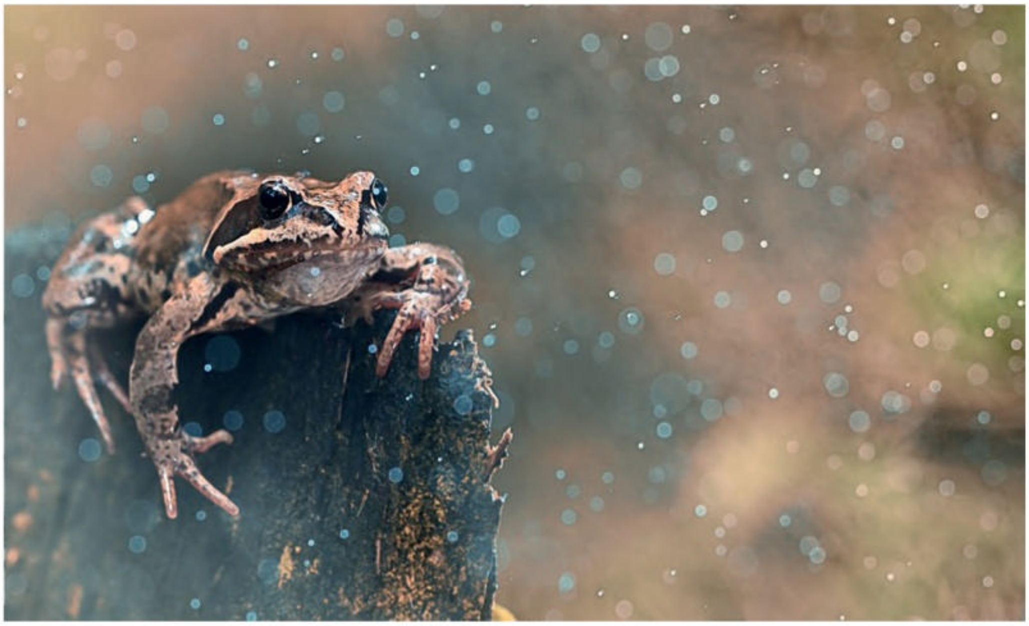


➤ **The fused toes of chameleons offer a different approach to arboreal life.**
Photo courtesy Oakland Images/www.shutterstock.com

⮝ **Females can lay up to 500 eggs, but even under good conditions, only a tiny fraction of the tadpoles will survive to become adult frogs.**
Photo courtesy Michael Benard/www.shutterstock.com

Road salt has potentially very serious consequences if used in wetland areas in particular, as far as amphibians are concerned. Photo courtesy Thee-Wee Gn/www.shutterstock.com

⮟ **Rain over several days in succession is one of the recognised triggers for breeding in wood frogs.**
Photo Kichigin/www.shutterstock.com



In the short-term and on the local scale, it's not possible for us to change these larger climate patterns. However, local management groups can be made aware of the exacerbating effects of pond contaminants on amphibians that breed too early, and this may help to mitigate the worst effects in some cases. "From an evolutionary perspective, it is fascinating to understand how animals can adapt, or fail to adapt, to rapid changes in their environment," she adds.

Further information

Nicholas Buss, Lindsey Swierk, Jessica Hua. **Amphibian breeding phenology influences offspring size and response to a common wetland contaminant.** *Frontiers in Zoology*, 2021; 18 (1) DOI: 10.1186/s12983-021-00413-0

Threatened rattlesnakes – the impact of inbreeding

The first look at a threatened rattlesnake species' recent genetic history suggests that inbreeding resulting from a limited habitat may not be as detrimental as theory would predict it to be. In fact, scientists speculate that eastern massasauga rattlesnakes *(Sistrurus catenatus)* may have pre-adapted to living in small, isolated populations – where the most dangerous genetic mutations that arose could be easily exposed and purged.

Researchers sequenced the genomes of 90 eastern massasauga rattlesnakes, which is a species listed as threatened under the US *Endangered Species Act* in 2016 because of loss and fragmentation of their wetland habitat. For comparison, the researchers also sequenced 10 genomes of a close relative, the western massasauga rattlesnake *(S. tergeminus),* a common reptile with no limitations on breeding opportunities and large populations.

⮝ **The eastern massasauga rattlesnake is under threat.**
Photo courtesy James Chiucchi.

Curbing problems

The Ohio State University team found that the most potentially damaging gene mutations were less abundant in the eastern rather than the western species. This finding suggests the breeding limitations of small, isolated populations might be accompanied by an evolutionary advantage of being able to elbow out genetic variants that get in the way of survival, suggests H. Lisle Gibbs, professor of evolution, ecology and organismal biology at Ohio State University.

⮜ **H. Lisle Gibbs has studied eastern massasaugas for over 20 years.**
Photo courtesy Ohio State University.

"This is something that has been reported very recently in other endangered species, but it's the first time that it's been shown in a reptile," Gibbs says. "We always worry about genetics and the loss of variation and what it means to be in a small population in which there's lots of inbreeding. At least in this species, maybe it's not such a big deal. And from a conservation perspective, perhaps we can downplay genetics and say ecology – such as habitat restoration – is more important."

Eastern massasauga rattlesnakes live in isolated spaces in midwestern and eastern North America, and evolutionary theory proposes that the inevitable inbreeding in such populations threatens species with extinction as genetic mutations accumulate. The smallest populations might reach 30 snakes, but Ohio's Killdeer Plains Wildlife Area is home to one of the most genetically diverse and largest populations in the country, numbering in the thousands.

Gibbs has studied eastern massasaugas for over two decades and, as director of the Ohio Biodiversity Conservation Partnership, advises the Ohio Department of Natural Resources on management of the species.

"Through years and years of study, we know that most populations are isolated, like little natural zoos scattered throughout the landscape," Gibbs said. "As a result of habitat degradation, we've known they show little variation – but we've never actually looked at variation in genes

The range of the eastern massasauga extends as far north as Ontario in Canada.
Photo courtesy Ryan M. Bolton/www.shutterstock.com

that code for things that matter to a rattlesnake."

New techniques used

Only recently has it been possible to apply the research techniques perfected with the human genome to work with this species. Gibbs and his research colleague Alexander Ochoa zeroed in on identifying mutations in genes that may affect survival and reproduction in order to gauge how hazardous inbreeding might be to eastern massasaugas.

Though a higher overall number of potentially deleterious mutations were found in the common western massasaugas, that didn't translate to more threats to their survival because most troublesome gene copies were offset by protective copies. That can happen only in heterozygotes, which have two different copies, or alleles, of a particular gene – one inherited from each parent. As the result of generations of inbreeding, eastern massasaugas are much more likely to have two copies of the same allele, displaying less genetic diversity.

CAUTION
SNAKE CROSSING
PROTECTED SPECIES

A warning sign about the presence of eastern massasauga rattlesnakes in Monroe, Michigan. This is Michigan's only venomous snake.
Photo courtesy ehrlif/www.shutterstock.com

"That's why inbreeding has impacts – because that's when you get two bad alleles showing up together, with no good allele to compensate, so there is a negative effect," Gibbs explains. "There's more inbreeding, so overall you get more mostly bad mutations together, but the really bad ones, because they're exposed, are also eliminated at a much greater rate."

An unexpected outcome

Through another analytical technique comparing the narrowing of the eastern and western massasauga genetic makeup over several hundred years, Gibbs and Ochoa confirmed the impact human activity has had on the eastern massasauga's swampy habitat. In contrast, western massasaugas live in grassy and woodland regions of the south-central United States that are less densely populated by humans.

"We looked at what has happened in these snakes and their population sizes over the last 300 years, which is when humans have been trampling all over North America, impacting the landscape," Gibbs says. "The effects in terms of reducing population sizes are greater in eastern than in western massasaugas over this period."

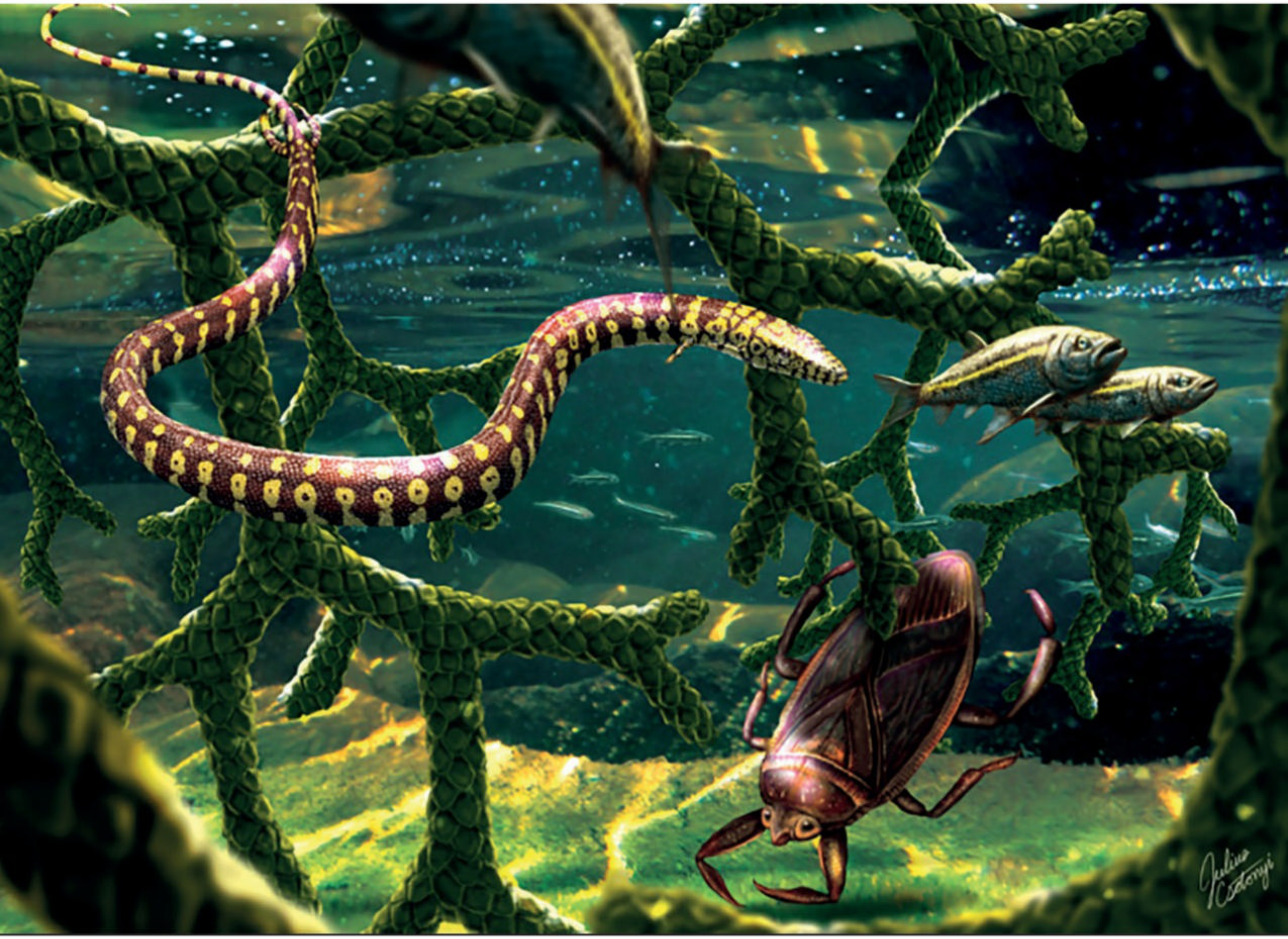
The findings could influence management decisions. A common conservation practice would involve introducing snakes from a more genetically diverse population into a highly isolated group to counter the effects of inbreeding. But it turns out that the eastern massasauga might benefit more from preservation of its habitat while the genetics takes care of itself.

"This counterintuitive result makes us rethink what living in a small population is, and whether genetic problems are as important as we think they are," Gibbs adds. "This is certainly not to say living in a small population isn't bad – it just may be that the genetic effects are not as bad as we thought."

Further information

Alexander Ochoa, H. Lisle Gibbs. **Genomic signatures of inbreeding and mutation load in a threatened rattlesnake.** *Molecular Ecology,* 2021; DOI: 10.1111/mec.16147

Missing link dismissed



▲ **In the shallows near the shore, *Tetrapodophis amplectus* swims through a tangle of branches from the conifer (*Duartenia araripensis*) that have fallen into the water, sharing this habitat with a water bug of the family Belostomatidae and small fish (*Dastilbe* species).** Artwork courtesy Julius Csotonyi.

Hopes of a major discovery

Being able to link the evolutionary chain together with a fossil of a 'snake with four legs', thereby connecting lizards and early snakes, would be a dream come true for researchers. Unfortunately however, a specimen formerly thought to fit the bill is now not the missing piece of the puzzle, according to the findings of a new study led by University of Alberta palaeontologist Michael Caldwell.

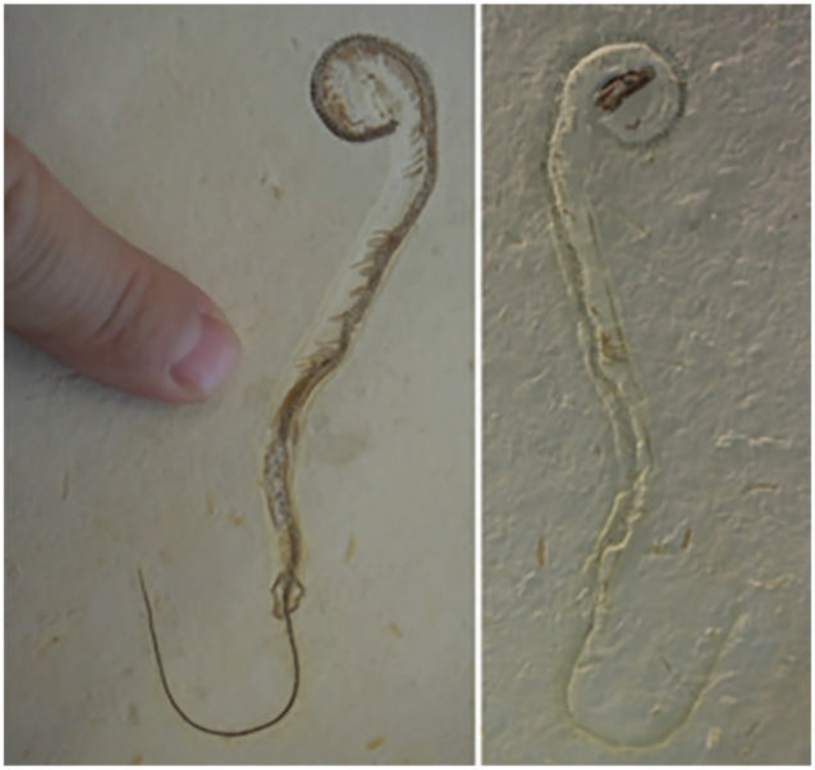
"It has long been understood that snakes are members of a lineage of four-legged vertebrates that, as a result of evolutionary specialisations, lost their limbs," explains Caldwell, who is a professor in the Departments of Biological Sciences and Earth and Atmospheric Sciences. "Somewhere in the fossil record of ancient snakes, there should be an ancestral form that still had four legs. It has therefore long been predicted that a fossil of this type would be unearthed at some point."

In a paper published back in 2015, another team of researchers reported the discovery of what they believed was an example of the first known four-legged snake fossil, naming the specimen as *Tetrapodophis amplectus*.

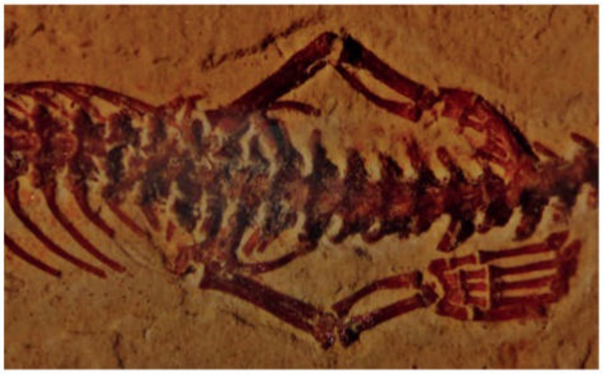
"If correctly interpreted, based on its preserved anatomy, this would obviously have been a very important discovery," says Caldwell.

Misplaced optimism

But he explains that this new study of *Tetrapodophis* has revealed a number of



Part and counterpart of *Tetrapodophis amphlectus* in the rock where the fossil formed. Photo courtesy Michael Caldwell.



The hind limbs of this puzzling fossil. Taken at the Burgmeister Muller Museum, Solnhofen in Germany. Photo courtesy Ghedoghedo/CC BY-SA 4.0.

mischaracterisations about the anatomy and morphology of the specimen — traits that initially seemed to be shared most closely with snakes, suggesting this might be the long-sought-after snake with four legs.

There are many evolutionary questions that could be answered by finding a four-legged snake fossil, but only if it is the real thing. The major conclusion of our team is that *Tetrapodophis amplectus* is not in fact a snake and was misclassified," claims Caldwell. "Rather, all aspects of its anatomy are consistent with the anatomy observed in a group of extinct marine lizards from the Cretaceous period known as dolichosaurs."

The evidence

The clues to this conclusion, Caldwell notes, were hiding in the rock from which the fossil was extracted. "When the rock containing the specimen was split, revealing the specimen, the skeleton and skull ended up on opposite sides of the slab, with a natural mould preserving the shape of each on the opposite side," he explains. "The original study only described the skull and overlooked the natural mould, which preserved several features that make it clear that *Tetrapodophis* did not have the skull of a snake — not even of a primitive one.

A controversial specimen

Although *Tetrapodophis* may therefore not be the highly-prized snake with four legs, it still has much to teach us, says fellow researcher Tiago Simões, a Brazilian palaeontologist who pointed out some of the features that make it unique.

"One of the greatest challenges of studying *Tetrapodophis* is that it is one of the smallest fossil squamates ever found," said Simões. "It is comparable to the smallest squamates alive today that also have reduced limbs."

Practical difficulties

An additional challenge to studying *Tetrapodophis* is access to the specimen itself. "There were no appropriate permits for the specimen's removal from Brazil and, since the original description was published, it has been housed in a private collection which gives only limited access to researchers. The situation was met with a large backlash from across the scientific community," claims Simões.

"In our redescription of *Tetrapodophis*, we also lay out the important legal status of the specimen and emphasise the necessity to have it repatriated to Brazil, in accordance not only with Brazilian legislation but also international treaties."

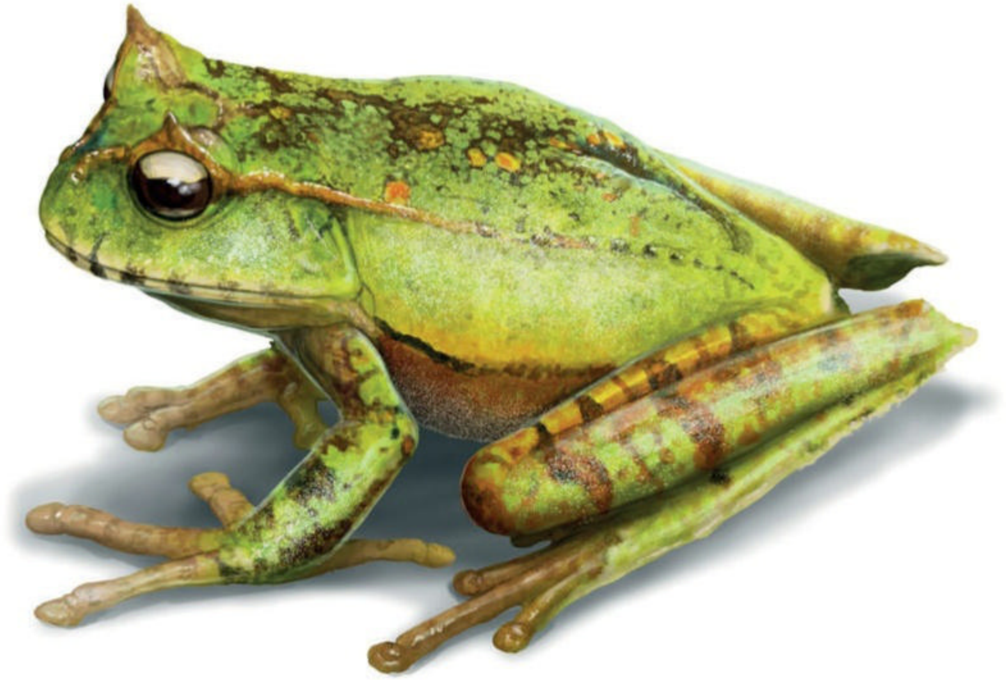
The fossil was unearthed in Brazil, from the early Cretaceous Crato Formation in Ceará, which lies in the east of the county, but it was subsequently taken overseas. Photo courtesy timyee/www.shutterstock.com

Further information

Michael W. Caldwell, Tiago R. Simões, Alessandro Palci, Fernando F. Garberoglio, Robert R. Reisz, Michael S. Y. Lee, Randall L. Nydam. ***Tetrapodophis amplectus* is not a snake: re-assessment of the osteology, phylogeny and functional morphology of an Early Cretaceous dolichosaurid lizard.** *Journal of Systematic Palaeontology*, 2021; 1 DOI: 10.1080/14772019.2021.1983044

Feared extinct: the only frog with true teeth on its lower jaw

After a century of debate, biologists have finally confirmed that just a single species of frog, out of the more than 7,000 living today, has true teeth on its lower jaw. This large marsupial frog, known to science as *Gastrotheca guentheri*, has puzzled scientists since its discovery in 1882 because it possesses what appeared to be a complete set of jagged, dagger-like teeth on the top and bottom of its mouth.



Guenther's marsupial frog is the only known member of the group to have true teeth on both its upper and lower jaws. Illustration courtesy Gabriel Ugueto.

Difficulties in studying these teeth

Since then, there has been considerable debate over the exact nature of these structures. True teeth are composed of specific tissues, including dentine and enamel, but these are notoriously difficult to observe in frogs' teeth because of their diminutive size.

"Each tooth is incredibly small, being about the size of a grain of sand," explains Daniel Paluh from University of Florida's Department of Biology. "There's no way to confirm the presence of dentine and enamel in frogs' teeth without using high-resolution techniques.

Earliest record

Frogs have lacked teeth on their lower jaw since their first appearance in the fossil record more than 200 million years ago. A single living species with a full dentition thus seemed unlikely at best and contradicted a long-standing biological theory, called Dollo's Law, which states that once a complex trait is lost in an organism, it never returns.

But frogs are known for flouting the rules when it comes to teeth. Although their basic body shape and anatomy have remained largely unchanged since the Jurassic period, Paluh and his colleagues recently determined that frogs have lost their teeth on more than 20 separate occasions and may have regained them an additional six times throughout their evolutionary history.

Different arrangements

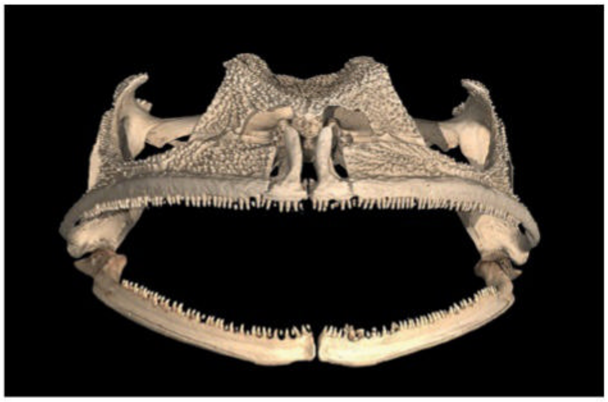
Some species, such as those that feed on ants and termites, are entirely toothless, relying instead on their sticky, projectile tongues to reel in food. Frogs that go after larger food items are often equipped with a row of teeth on their upper jaw plus a toothy, serrated palate on the top of their mouths, which helps to keep wiggling prey from escaping.

In rare cases, some species have evolved large bony fangs that protrude from their lower jaw and superficially resemble teeth but lack the tell-tale dentine and enamel tissues. And instead of the conveyor-belt system of tooth replacement in other frogs, fangs grow only once and cannot be replaced.

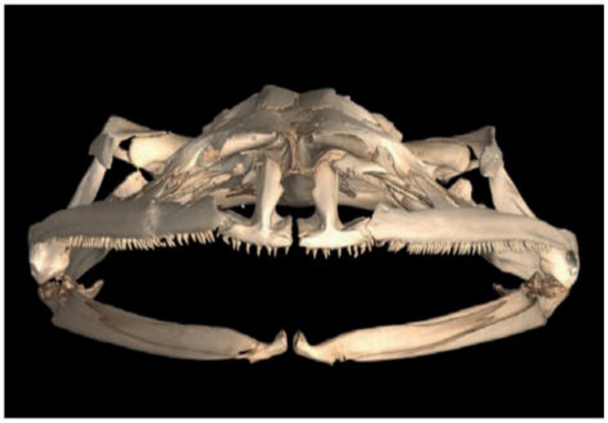
True or false?

For decades, no one was sure whether the structures on the lower jaw of Guenther's marsupial frog were bones masquerading as teeth or the real thing. Finding a specimen to settle the question wasn't easy either. Native to the cloud forests of Colombia and Ecuador, the last recorded observation of the species was made in 1996, prompting serious concerns that it may now be extinct.

A small number of these frogs are preserved as museum specimens, but given their rarity, biologists are hesitant to subject them to the type of destructive analyses that would be required to study their teeth. But Paluh was able to capitalise on a peculiar feature of the biology of *Gastrotheca*



CT scans of a Guenther's marsupial frog skull revealed what appeared to be identical rows of teeth on both the upper and lower jaws, which researchers later confirmed by further study. Florida Museum image courtesy Dan Paluh.



▲ The majority of frogs, such as this species in the genus *Pelophylax*, are entirely toothless on their lower jaw. Florida Museum image courtesy Dan Paluh.

Frogs in the genus *Gastrotheca* possess a pouch on their back, which they use to carry and protect fertilised eggs. Photo by Jose Ulisses Araujo de Souza/CC-BY-NC.

species to use a preserved embryo for study rather than a full-sized adult.

Instead of laying eggs in ponds or streams, female marsupial frogs carry them around in a pouch on their back. "In the case of Guenther's marsupial frog, these eggs will skip the tadpole stage and hatch directly into miniature versions of the adult, described as froglets," Paluh explains.

Staining provides answers

The researchers took CT scans of the embryo's jaws and carefully stained razor-thin sections of individual teeth with dyes that bind to enamel and dentine, obtaining unequivocal results. The teeth of Guenther's marsupial frog were virtually identical to those of other frog species in their overall shape, development and the tissues present in them.

"This was surprising given the extreme length of time since they were lost and regained," Paluh said. "Our expectation was that if they did regain teeth, they would somehow be different, but that's not what we saw at all."

As to how structures that have remained absent for millions of years reappeared in an otherwise unassuming frog, Paluh suspects the answer resides in the complex pathway of dental development retained in the majority of living amphibians. Although the location of teeth can vary from species to species, the same basic genetics probably underlies their development, and producing them on the lower jaw might be as simple as effectively throwing a switch.

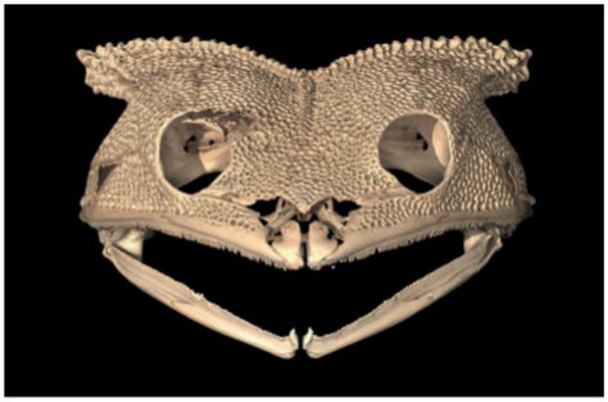
An uncertain outcome

Paluh plans on leveraging several genetic tools in the near future to map the contours of tooth development and evolution in frogs, but for Guenther's marsupial frog and a host of other imperilled species in the American tropics, finding the exact answer may no longer be possible. DNA degrades over time in plants and animals stored in museum collections, and the scant number of aging *G. guentheri* specimens aren't likely to be viable resources for genetic study.

"We've seen many species in this group become endangered or even vanish because of climate change, habitat degradation and chytrid fungus disease," Paluh says. "And unfortunately, we won't be able to answer these questions in any other group because these traits don't exist anywhere else in the frog tree of life."

Further information

Daniel J. Paluh, Wesley A. Dillard, Edward L. Stanley, Gareth J. Fraser, David C. Blackburn. **Re-evaluating the morphological evidence for the re-evolution of lost mandibular teeth in frogs.** *Evolution*, 2021; DOI: 10.1111/evo.14379



▼ Faux fangs! This species of frog in the genus *Hemiphractus* sports bony fangs and a finely serrated jawline that aid in capturing prey. Florida Museum image courtesy Dan Paluh.

▲ The DNA in museum specimens breaks down over time. Photo courtesy Degimages/www.shutterstock.com

LIVE LONG AND PROSPER!

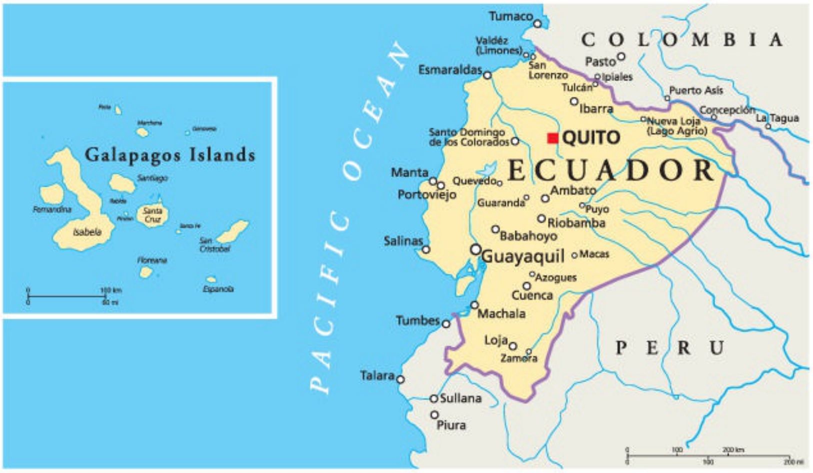
Galápagos giant tortoises have a phenomenal lifespan.
Photo courtesy FOTOGRIN/www.shutterstock.com

Galápagos giant tortoises can weigh well over 136kg (300lb) and often live for more than 100 years. So what's the secret to their evolutionary success?

A new study concludes that compared with other chelonians, these particular reptiles evolved to have extra copies of genes — called duplications — that may protect against the ravages of ageing, including various forms of cancer.

Specific defences

Laboratory tests on Galápagos giant tortoise cells corroborate the idea that


Galapagos Islands
Pinta
Marchena
Genovesa
Santiago
Fernandina
Rabida
Pinzon
Santa Cruz
Santa Fe
Isabela
San Cristobal
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Española
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60 mi
PACIFIC OCEAN
COLOMBIA
ECUADOR
PERU
Tumaco
Valdéz (Limones)
San Lorenzo
Esmaraldas
Pasto
Ipiales
Tulcán
Ibarra
Puerto Asís
Concepción
La Tagua
Nueva Loja (Lago Agrio)
Santo Domingo de los Colorados
QUITO
Manta
Portoviejo
Quevedo
Ambato
Guaranda
Puyo
Riobamba
Babahoyo
Salinas
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Azogues
Cuenca
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➤ The Galápagos islands are volcanic outcrops located off the coast of Ecuador, South America. The ancestors of the tortoises there today are thought to have drifted from the mainland, and colonised the islands, evolving into distinctive populations.
Photo courtesy Peter Hermes Furian/www.shutterstock.com

these animals have developed such defences, says Vincent Lynch, an evolutionary biologist at the University at Buffalo (UB) in New York state.

Specifically, experiments showed that the cells of this gigantic chelonian are highly sensitive to certain types of stress, relating to damaged proteins.

When exposed to these pressures, the cells self-destruct much more readily than other turtle cells through a process called apoptosis. Destroying these flawed cells before they have the chance to form tumours could help the tortoises evade cancer, according to Lynch.

"In the lab, we can stress the cells out in ways that are associated with aging and see how well they resist that distress. And it turns out that the Galápagos tortoise cells are really, really good at killing themselves before that stress has a chance to cause diseases like cancer," says Lynch, who is associate professor of biological sciences in the UB College of Arts and Sciences.

Combating cancers

The findings are particularly intriguing because — all things being equal — huge animals that live for a long time should have the highest cancer rates. That's because large, long-lived creatures have many more cells, and the more cells that a body has, so the more opportunities there are for cancerous mutations to arise.

One major focus of Lynch's work is understanding the biological mechanisms that help big animals like Galápagos tortoises live long and prosper, with elephants being another area of his team's study. Although this research is driven primarily by curiosity, the resulting findings could have practical implications too.

"When you can identify the way in which nature has done something — such as how certain species have evolved protections — maybe you can find a way to translate those discoveries into something that benefits human health and disease?" Lynch suggests. "We're not going to go treating humans with Galápagos tortoise genes, but perhaps we could find a drug that mimics certain important functions."

The value of biodiversity

Research of this kind also underscores the value of conservation. "Studies like this demonstrate why preserving biodiversity is so important," says Lynch's colleague Scott Glaberman, an assistant professor of environmental science and policy at George Mason University.

"Extreme species like Galápagos giant tortoises probably hold many secrets for dealing with major human challenges like ageing and cancer, and even climate change. Our study also shows that even within turtles, different species look, act and function differently, and losing any species to extinction means that a piece of unique biology will be lost to the world forever."

⮝ The cellular structure of Galápagos tortoises appears to protect them from cancers.
Photo courtesy Ylenia Chiari.

⮜ A young Galápagos tortoise should have a long and healthy life. Its secrets may help us to gain a better insight into the ageing process generally.
Photo courtesy Jess Kraft/ www.shutterstock.com

Further information

Scott Glaberman, Stephanie E Bulls, Juan Manuel Vazquez, Ylenia Chiari, Vincent J Lynch. **Concurrent evolution of anti-aging gene duplications and cellular phenotypes in long-lived turtles.** *Genome Biology and Evolution*, 2021; DOI: 10.1093/gbe/evab244

A long-distance traveller?

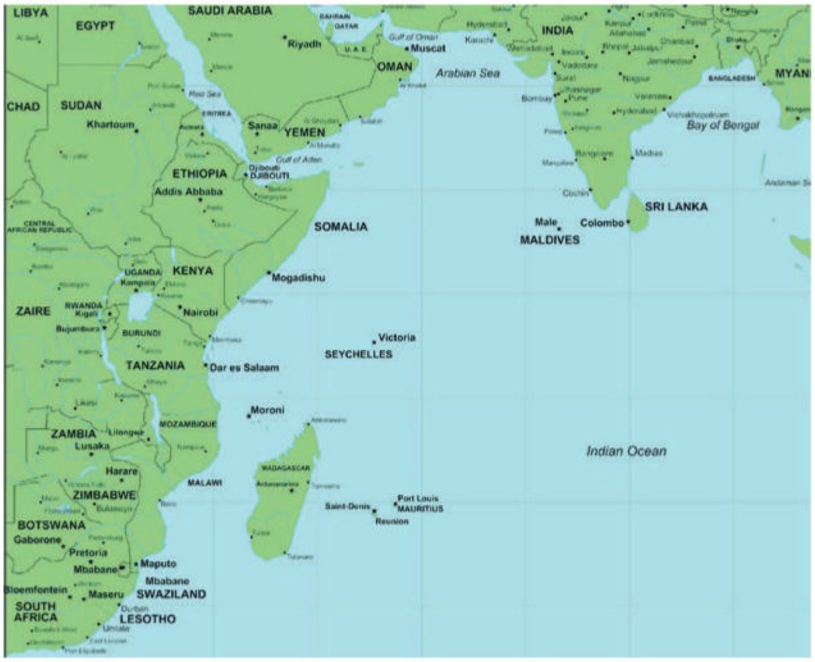
⮝ The globe skimmer dragonfly seen in close-up.
Photo courtesy Aryut Tantisoontornchai/www.shutterstock.com

In 2009, marine biologist Charles Anderson proposed the idea that the globe skimmer dragonflies (*Pantala flavescens*) he saw on the Maldives must have flown to the islands from what he assumed was India. When they took off again, he noticed how they appeared to be flying towards East Africa. Twelve years later, a group of researchers have set out to investigate his claim.

Huge distances

Is it feasible that dragonflies could be capable of undertaking a migration of this distance, and returning back to India? An international research team led by Lund University in Sweden has used models and simulations to find out if it could be feasible.

Unfortunately, globe skimmer dragonflies are too small to be fitted


LIBYA
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SAUDI ARABIA
Riyadh
Gulf of Oman
Muscat
OMAN
INDIA
Arabian Sea
Bay of Bengal
BANGLADESH
CHAD
SUDAN
Khartoum
Red Sea
ERITREA
Sanaa
YEMEN
Gulf of Aden
ETHIOPIA
Djibouti
DJIBOUTI
Addis Abbaba
SOMALIA
Cochin
Madras
SRI LANKA
Male
Colombo
MALDIVES
UGANDA
Kampala
KENYA
Mogadishu
ZAIRE
RWANDA
Kigali
Nairobi
Bujumbura
BURUNDI
TANZANIA
Dar es Salaam
Victoria
SEYCHELLES
Moroni
ZAMBIA
Lilongwe
Lusaka
MOZAMBIQUE
Indian Ocean
Harare
MALAWI
MADAGASCAR
ZIMBABWE
Port Louis
MAURITIUS
Saint-Denis
Reunion
BOTSWANA
Gaborone
Pretoria
Mbabane
Maputo
Mbabane
SWAZILAND
Bloemfontein
Maseru
SOUTH AFRICA
LESOTHO
Durban

➤ These dragonflies were observed flying over vast areas of ocean, starting from the Maldives off the southwestern coast of India, travelling to East Africa.
Photo courtesy Indian Summer/www.shutterstock.com

with transmitters. So instead, the researchers examined their physiological behaviour and calculated how long a globe skimmer dragonfly could stay airborne using the energy that can be stored in its body. In addition, the researchers used meteorological wind models to determine if there are winds that can facilitate the migratory movements of these insects in both directions.

The outcome

"Our study reveals that this migration from India to East Africa is actually possible. However, the globe skimmer dragonfly can't manage it using only the fat it can store in its body. It also requires favourable winds and these are only present during certain periods of the year," reveals Johanna Hedlund, a biology researcher at Lund University.

According to the simulated migration experiments using wind models, about 15 per cent of the dragonflies could manage the migration from India to Africa in the spring. In the autumn, 40 per cent could make the same journey in the opposite direction.

Johanna Hedlund and her colleagues consider it remarkable that dragonflies can do this at all. Even more impressive is the fact that the globe skimmer dragonfly's migration across the Indian Ocean is the longest in the animal kingdom, in relation to an animal's size. "We have now got a lot closer to solving the mystery of how a tiny dragonfly, which only weighs 300 milligrams (0.01oz), can cross 2000km (1245ml) of open sea," says Johanna Hedlund.

▲ A globe skimmer dragonfly resting.
Photo courtesy Johanna Hedlund.

➤ These dragonflies can fly thousands of kilometres using their lace-like wings.
Photo courtesy Johanna Hedlund.

▼ The jacobin cuckoo is another species that crosses the Indian Ocean on favourable winds.
Photo courtesy Sandeep kumar priyadarshi/www.shutterstock.com

Impacts of climate change

Other creatures are known to rely on favourable wind conditions when they migrate. Two examples are the Amur falcon (*Falco amurensis*) and the jacobin cuckoo (*Clamator jacobinus*), which also both fly across the Indian Ocean. The researchers involved in the dragonfly study warn that climate change may affect the chances of these birds and the globe skimmer dragonfly making such crossings successfully in the future. There is a risk that wind patterns will change when the water surface gets warmer.

▲ Climate change could impact on the flight patterns of these insects.
Photo courtesy Dave Hansche/www.shutterstock.com

Wider implications

This study is important in several broader aspects as well. It creates an understanding of the distances that one of the animal kingdom's smallest migrants can cover, it increases knowledge about how migratory animals could potentially spread diseases, and it also contributes to ecosystem understanding at widespread locations around the world.

Further information

Johanna S. U. Hedlund, Hua Lv, Philipp Lehmann, Gao Hu, R. Charles Anderson, Jason W. Chapman. **Unraveling the World's Longest Non-stop Migration: The Indian Ocean Crossing of the Globe Skimmer Dragonfly.** *Frontiers in Ecology and Evolution*, 2021; 9 DOI: 10.3389/fevo.2021.698128

How spiders are programmed to build webs

⮝ Spiders can create both beautiful and complex webs. This particular web has been constructed by a European garden spider (*Araneus diadematus*).

Researchers at Johns Hopkins University in Maryland in the USA have discovered precisely how spiders build webs, by utilising night vision and artificial intelligence to track and record every movement of all eight legs as the spiders worked in the dark. Their subsequent creation of a web-building playbook or algorithm brings new understanding of how creatures with brains that are a fraction of the size of ours can create structures of such elegance, complexity, and geometric precision.

Webs can be encountered at different heights - even close to the ground as seen here.
Photo courtesy ANDREI RASPUTIN/www.shutterstock.com

New insight

"I first got interested in this topic while I was out birding with my son," says Andrew Gordus, a behavioural biologist in the Department of Biology in the Krieger School of Arts and Sciences. "After seeing a spectacular web, I thought that if you went to a zoo and saw a chimpanzee building this, you'd think that's one amazing and impressive chimpanzee!

"Well, this is even more amazing because a spider's brain is so tiny and I was frustrated that we didn't know more about how this remarkable behaviour occurs. Now we've defined the entire choreography for web building, which has never been done for any animal architecture at this resolution."

An architectural achievement

Web-weaving spiders that build blindly using only the sense of touch have fascinated humans for centuries. Not all spiders build webs but those that do are among a subset of animal species known for their architectural creations, like nest-building birds and puffer fish that create elaborate sand circles when mating.

The first step to understanding how the relatively small brains of these animal architects support their high-level construction projects is to systematically document and analyse the behaviours and motor skills involved. Up until now, this has never been done, mainly because of the challenges of capturing and recording the actions, according to Gordus.

In this instance, his team studied a hackled orb weaver (*Uloborus glomosus*), a spider native to the western United States that is small enough to sit comfortably on a fingertip.

Special technology

In order to observe the spiders during their nighttime web-building work, the lab designed an arena with infrared cameras and infrared lights. This set-up allowed them to monitor and record six spiders every night as they constructed webs. They tracked the millions of individual leg actions with machine vision software designed specifically to detect limb movement.

"Even if you video record it, that's a lot of legs to track, over a long time, across many individuals," says Abel Corver, who is studying web-making and neurophysiology. "It's just too much to go through every frame and annotate the leg points by hand so we trained machine vision software to detect the posture of the spider, frame by frame, enabling us to document everything the legs do to build an entire web."

A spider seen in close-up spinning its web. The researchers used specially-designed equipment for their study.
Photo courtesy ResiLente/www.shutterstock.com

The outcomes

They found that web-making behaviours are quite similar across spiders, so much so that the researchers were ultimately able to predict the part of a web a spider was working on just from seeing the position of a leg.

"Even if the final structure is a little different, the rules they use to build the web are the same," Gordus explains. "They're all following the same rules, which confirms that these are encoded in their brains. Now we want to know how those rules are encoded at the level of neurons."

Future work for the lab includes experiments with mind-altering drugs to determine which circuits in the spider's brain are responsible for the various stages of web-building. "The spider is fascinating because here you have an animal with a brain built on the same fundamental building blocks as our own, and this work could give us hints about how we can understand larger brain systems, including that of humans, which I think is very exciting," Corver adds.

Further information

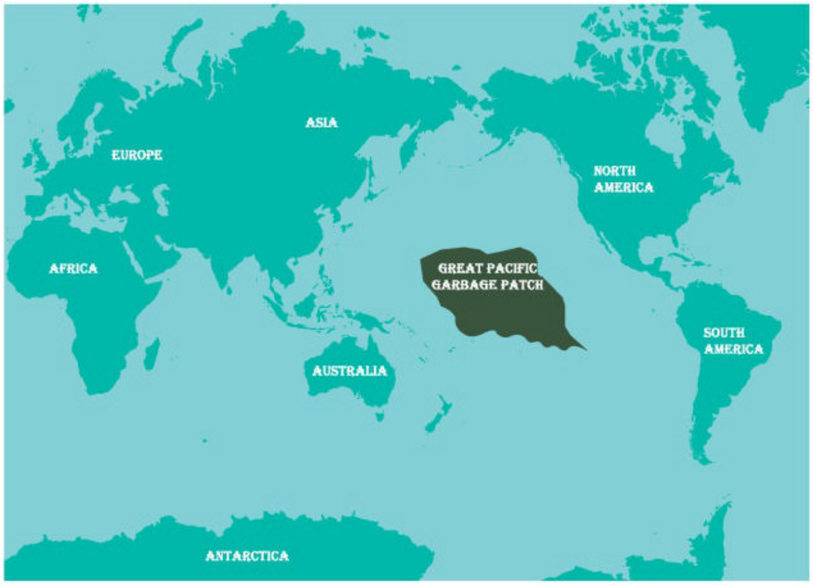
Abel Corver, Nicholas Wilkerson, Jeremiah Miller, Andrew Gordus. **Distinct movement patterns generate stages of spider web building.** *Current Biology,* 2021; DOI: 10.1016/j.cub.2021.09.030

⌃ **Web-making is quite similar in all species of spider that display this behaviour.** Photo courtesy Milena_/www.shutterstock.com

A hackled orbweaver spider of the family Uloboridae on its web.
Photo courtesy Vinicius R. Souza/www.shutterstock.com

Plastic creates ‘evolutionary trap’ for young sea turtles

⮝ Turtles can be attracted to plastic bags in the ocean because they resemble jellyfish.
Photo courtesy Rich carey/ www.shutterstock.com



➤ The location of the Great Pacific Garbage Patch.
Map courtesy Elime/www. shutterstock.com

A new study, led by the University of Exeter in the UK, found plastic inside small juvenile turtles along both the east (Pacific) and west (Indian Ocean) coasts of Australia. The research team included Murdoch University, the Department of Environment and Science (Queensland) and the Department of Biodiversity Conservation and Attractions (Western Australia).

Sucked into the Garbage Patch

After hatching on beaches, sea turtles travel on currents and spend their early years in the open ocean. But these currents now accumulate vast quantities of plastic and – feeding near the surface – many young turtles swallow it. “Juvenile turtles have evolved to develop in the open ocean, where predators are relatively scarce,” explains Dr Emily Duncan, of the Centre for Ecology and Conservation on Exeter’s Penryn Campus in Cornwall.

“However, our results suggest that this evolved behaviour now leads them into a ‘trap’ – bringing them into highly polluted areas, notably the Great Pacific Garbage Patch. Juvenile sea turtles generally have no specialised diet – they eat anything, and our study suggests this includes plastic. We don’t yet know what impact ingesting plastic has on juvenile turtles, but any losses at these early stages of life could have a significant impact on their population levels.”

Researchers examined juvenile sea turtles (from hatchlings up to those with a shell measurement of 50cm (20in)) that either washed up or were accidentally caught by fishing on the coasts of Australian coasts. In total, the study included 121 sea turtles representing five of the world’s seven species: green, loggerhead, hawksbill, olive ridley and flatback turtles.

Different results

The proportion of turtles containing plastic was far higher on the Pacific coast affecting 86% of loggerheads, 83% of greens, 80% of flatbacks and 29% of olive ridleys. In comparison, on

➤ The fused toes of chameleons offer a different approach to arboreal life. Photo courtesy Oakland Images/www.shutterstock.com

⮝ Loggerhead turtles in the survey seemed to be particularly vulnerable to consuming plastics. Photo courtesy Wet Lizard Photography/www.shutterstock.com

the Indian Ocean coast, 28% of flatbacks, 21% of loggerheads and 9% of green turtles had consumed plastic. No plastic was found in hawksbill turtles on either coast, but only seven hawksbills were found so this sample size was small.

Plastic in the Pacific turtles was mostly hard fragments, which could come from a vast range of products used by people, while Indian Ocean plastics were mostly fibres – possibly from fishing ropes or nets. The polymers most commonly ingested by turtles in both oceans were polyethylene and polypropylene. “These polymers are so widely used in plastic products that it’s impossible to pin down the likely sources of the fragments we found,” Dr Duncan adds.

“Hatchlings generally contained fragments up to about 5-10mm (0.2-0.4in) in length, and particle sizes went up along with the size of the turtles. The next stage of our research is to find out if and how plastic ingestion affects the health and survival of these turtles. This will require close collaboration with researchers and veterinarians around the world.”

⮝ Fragments of plastic washed up on a beach. Photo courtesy SannePhoto/www.shutterstock.com

Further information

Emily M. Duncan, Annette C. Broderick, Kay Critchell, Tamara S. Galloway, Mark Hamann, Colin J. Limpus, Penelope K. Lindeque, David Santillo, Anton D. Tucker, Scott Whiting, Erina J. Young, Brendan J. Godley. **Plastic Pollution and Small Juvenile Marine Turtles: A Potential Evolutionary Trap.** *Frontiers in Marine Science*, 2021; 8 DOI: 10.3389/fmars.2021.699521

Gigantic flying reptile found in Australia

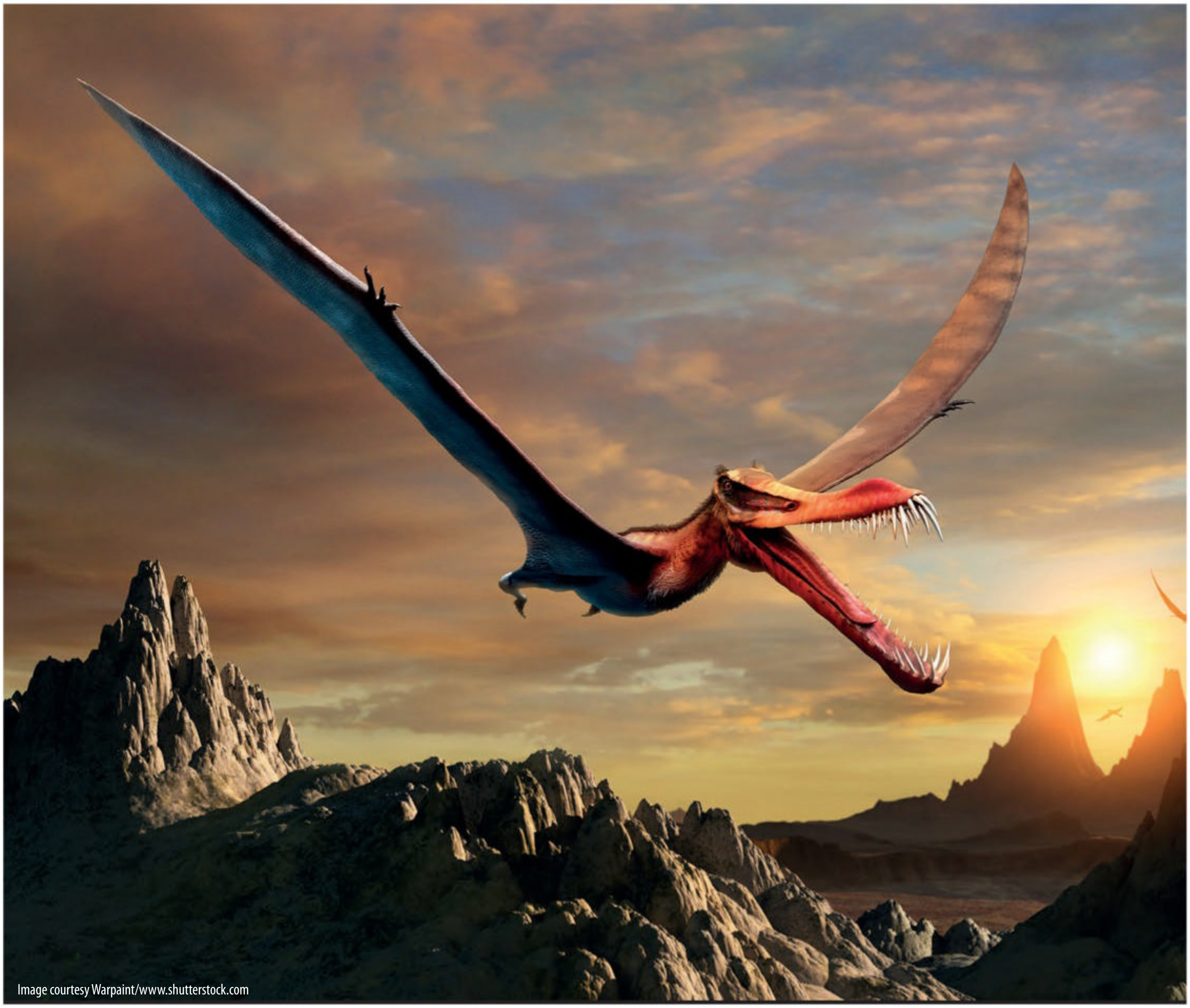


Image courtesy Warpaint/www.shutterstock.com

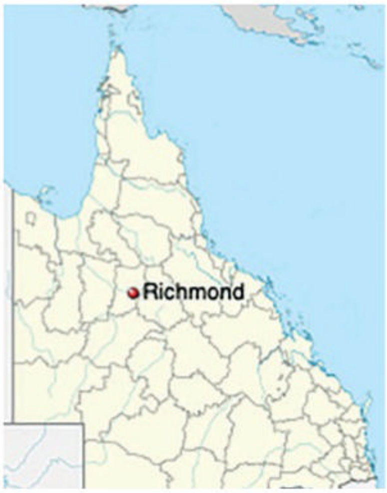
Australia's largest flying reptile has been uncovered by researchers from the University of Queensland (UQ). It was a pterosaur with an estimated 7m (23ft) wingspan that soared like a terrifying gigantic dragon above the ancient, vast inland sea that once covered much of outback in the state of Queensland.

Tim Richards, from the Dinosaur Lab in UQ's School of Biological Sciences, led a research team that analysed a fossil of the creature's jaw, discovered on Wanamara Country, near Richmond in north-west Queensland. "It's the closest thing we have to a real-life dragon," he says.

How it appeared

"The new pterosaur, which we have named *Thapunngaka shawi*, would have been a fearsome beast, with a spear-like mouth and a massive wingspan. It was essentially just a skull with a long neck, bolted on a pair of long wings. It would have been quite a savage predator, casting a great shadow over its prey which wouldn't have been aware of its presence until it was too late."

Mr Richards says the skull alone was just



▲ **The location where the fossil was discovered was close to Richmond, in Queensland.**
Map courtesy NordNordWest; Own work, using United States National Imagery and Mapping Agency data World Data Base II data Australian Government, Department of Infrastructure, Transport, Regional Development and Local Government. CC BY-SA 3.0 de.

▲ **The region today - it was once a vast inland sea.**
Photo courtesy Ron Gale/John Oxley Library/State Library of Queensland/Wikipedia/CC BY-SA 3.0

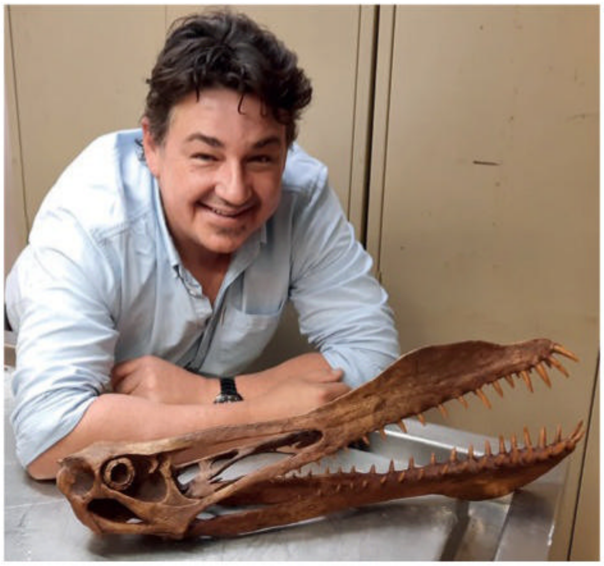
over 1m (3ft) long and contained around 40 sharp teeth, which would have been perfectly suited to grasping the large predatory fishes known to inhabit Queensland's no-longer-existent Eromanga Sea.

Pterosaurs as a group

"Even though pterosaurs could fly, they were nothing like birds, or even bats," explains Tim Richards. "Pterosaurs were a successful and diverse group of reptiles – the very first back-boned animals to begin the era of powered flight."

The new species belonged to a group of pterosaurs known as anhanguerians, which inhabited every continent during the latter part of the Age of Dinosaurs. Being perfectly adapted to powered flight, pterosaurs had thin-walled and relatively hollow bones.

Given these adaptations however, this means that their fossilised remains are rare and often poorly preserved. "It's quite amazing fossils of these animals exist at all," Mr Richards says. "By world standards, the Australian pterosaur record is poor, but the discovery of *Thapunngaka* contributes greatly to our understanding of Australian pterosaur diversity."



▼ **Tim Richards with the skull of the recently-discovered pterosaur.**
Photo courtesy University of Queensland.

Distinctive features

His colleague Dr Steve Salisbury explains that what was particularly striking about this new species of anhanguerian was the massive size of the bony crest on its lower jaw, which it presumably had on the upper jaw as well.

"These crests probably played a role in the flight dynamics of these creatures, and hopefully future research will deliver more definitive answers on this subject," Dr Salisbury adds. *Thapunngaka* is only the third species of anhanguerian pterosaur known from Australia, with all three species hailing from western Queensland.

How its name was chosen

The fossil was discovered in a quarry by Len Shaw, a local fossicker who has been 'scratching around' in the area for decades. The name of the new species honours the First Nations peoples of the Richmond area where the fossil was found, incorporating words from the now-extinct language of the Wanamara Nation.

"The genus name, *Thapunngaka*, links *thapun* [pronounced ta-boon] and *ngaka* [nga-ga], which are the Wanamara words for 'spear' and 'mouth' respectively," Dr Salisbury explains. "The species description of *shawi*, honours the fossil's discoverer Len Shaw, so the name literally means 'Shaw's spear mouth'." The fossil is now on display near where it was discovered, at Kronosaurus Korner in Richmond.

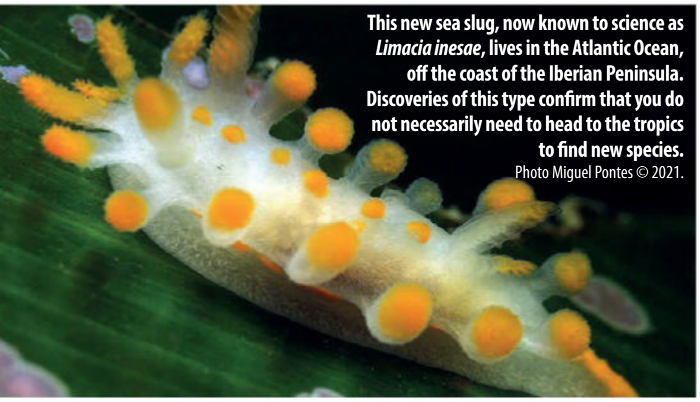
Further information

Timothy M. Richards, Paul E. Stumkat, Steven W. Salisbury. **A new species of crested pterosaur (Pterodactyloidea, Anhangueridae) from the Lower Cretaceous (upper Albian) of Richmond, North West Queensland, Australia.** *Journal of Vertebrate Paleontology*, 2021; e1946068 DOI: 10.1080/02724634.2021.1946068

New species found

In spite of the numerous problems posed by the pandemic, researchers at the California Academy of Sciences added another 70 new plant and animal species to the tree of life during 2021, enriching our understanding of Earth's biodiversity and strengthening our ability to make informed conservation decisions. The new species include 14 beetles, 12 sea slugs, nine ants, seven fish, six scorpions, five sea stars, five flowering plants, four sharks, three spiders, two sea pens, one moss, one pygmy pipehorse, and one caecilian. More than a dozen Academy scientists — along with several dozen international collaborators — described these new species.

⮝ The pygmy pipehorse *(Cylix tupareomanaia)*, represents a new genus and species, making it one of the most significant new aquatic species found this year. It occurs off the coast of Northland, New Zealand. Photo Richard Smith © 2021.



This new sea slug, now known to science as *Limacia inesae*, lives in the Atlantic Ocean, off the coast of the Iberian Peninsula. Discoveries of this type confirm that you do not necessarily need to head to the tropics to find new species.
Photo Miguel Pontes © 2021.

Finds around the world

Proving that our vast and dynamic planet still contains unexplored places with never-before recorded plants and animals, the scientists made their finds across five continents and three oceans, sifting through forest floors, venturing into vast deserts, and diving to extreme ocean depths. Their results help advance the Academy's mission to regenerate the natural world through science, learning, and collaboration.

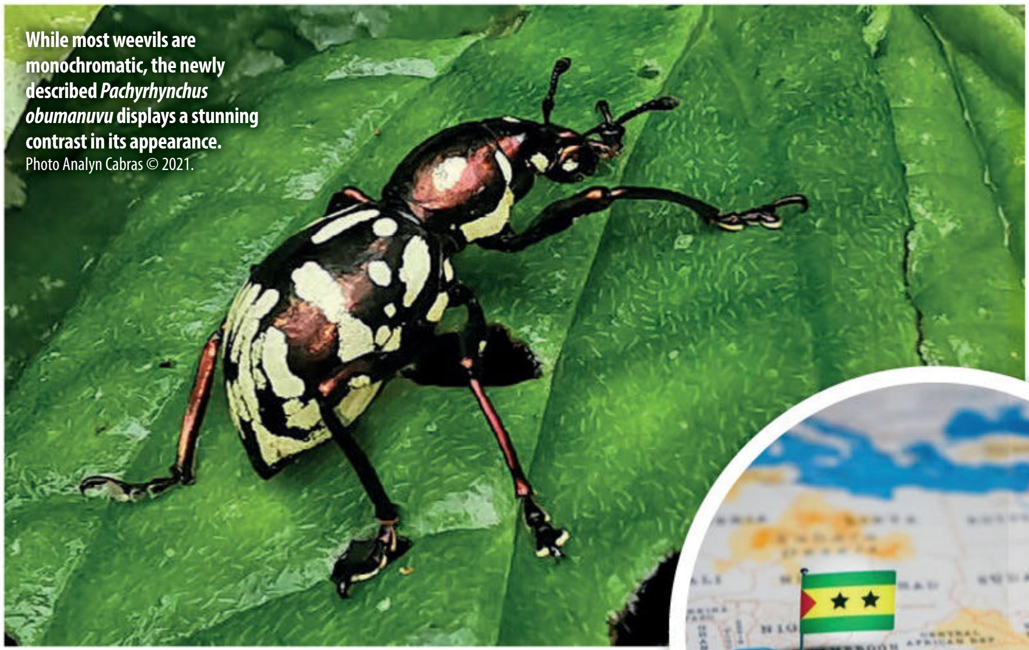
"Biodiversity is critical for the health of our planet, and is being lost at a rate where sustainability practices are no longer enough," says Academy virologist and Chief of Science Shannon Bennett, PhD. "As stewards of our natural world, we need to play an active role in regenerating ecosystems. Our relationship to nature improves with each new species, deepening our understanding of how our planet works and can best respond to an uncertain future. As we continue to battle a changing climate and a global pandemic, there has never been a more crucial time to protect the variety of life on Earth."

Although the Academy reported no new species of reptile this year, there were a number of new invertebrates and an amphibian featured on the list. Here are some of the stories associated with these discoveries.

Weevils on the edge

Matthew Van Dam, PhD, describes *Pachyrhynchus obumanuvu*, a brightly coloured weevil from the forested mountain tops of the Philippines. Found at 914m (3000ft) above sea level, these weevils live in the canopy of the moist, moss-covered cloud forest. Unlike most weevils, which tend to be a single colour, *P. obumanuvu* boasts complex iridescent patterns. Its colouration mimics the traditional garments of its namesake, the indigenous Obu Manuvu tribe.

But collaborating researcher Analyn Cabras, PhD, had additional motivations in terms of naming this species. "We are in a race against time under the constant threat of forest degradation," Cabras explains. "Many insects may go extinct before they are even discovered." *P. obumanuvu* was found in a small patch of primary forest — one of few remaining in the



While most weevils are monochromatic, the newly described *Pachyrhynchus obumanuvu* displays a stunning contrast in its appearance. Photo Analyn Cabras © 2021.

region due to centuries of farming and overlogging.

Cabras notes the power of a name to instil a sense of pride and stewardship for a species within a community. She highlights the importance of continued species identification, particularly in regions faced with rapid exploitation of natural resources. "How can we teach conservation and wildlife regeneration," Cabras questions, "if we can't put a name to a face?"

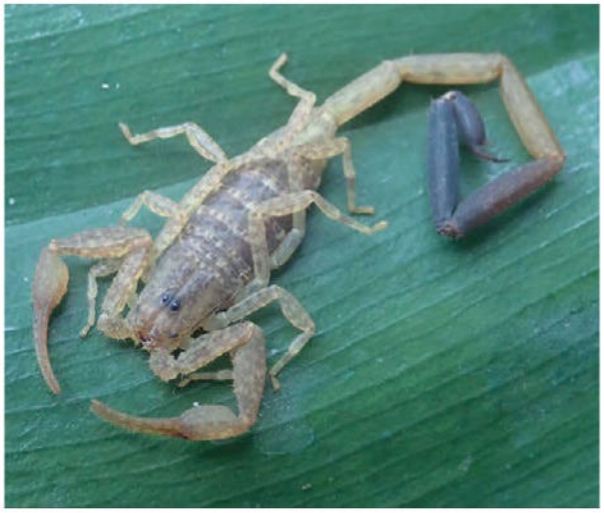
Scorpions reach new heights

In the canopies of Mexico's tropical lowland forests, you'll find unexpected residents: scorpions. This year, *Islands 2030* initiative co-leader and Curator of Arachnology Lauren Esposito, PhD, and graduate student Aaron Goodman described six new species of bark scorpions from Guatemala and Mexico.

While people might generally associate scorpions with arid desert climates, these bark scorpions find respite from predators, namely larger scorpions, high in the treetops of undisturbed primary forests. One of the new-to-science scorpions, *Centruroides catemacoensis*, has developed an extraordinary tactic to escape predators. With the ability to discern rustling winds from an approaching predator, *C. catemacoensis* will let go of its perch at the first sign of a nearby threat, falling to the safety of the forest floor.

"Once they hit the leaf litter, you won't find them," Goodman says. Goodman used this to his advantage while on night surveys, tapping branches with PVC pipes to mimic predators and trigger the scorpions to fall into the nets waiting below.

This bark scorpion (*Centruroides berstoni*) resides high in the treetops of Guatemala's tropical forests. Photo Aaron Goodman. © 2021 California Academy of Sciences.



Caecilian sleuthing in São Tomé

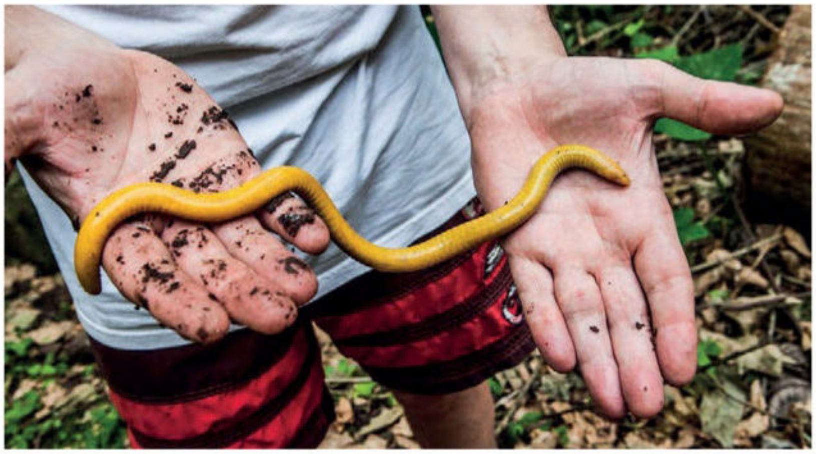
Since colonial times, biologists have debated whether or not the São Tomé caecilian — a limbless, burrowing amphibian — is one or two distinct species. After carefully studying the genetic markers of 85 individuals across São Tomé island in the Gulf of Guinea, *Islands 2030* initiative co-leader and Academy Curator of Herpetology Rayna Bell, PhD, provides the strongest evidence to date that the island boasts two unique species of caecilians.

Around 300,000 years ago, a burst of volcanic activity streaked São Tomé with lava flows dividing the island — and the caecilians — into unique, isolated habitats. This separation probably caused the original species to diverge into two at this stage, as each adjusted to the environmental pressures of their new-found territories.

As the lava flows subsequently eroded, the once-impenetrable barriers disappeared, allowing the two resulting species to become neighbours once more. Millennia of interbreeding and hybridisation has since shrouded the presence of two species by blurring the genetic lines between them. While the long debate over this species is familiar, Bell's finding is a major step towards understanding and protecting both of São Tomé's caecilians.

SUDAN
NIGERIA
CAMEROON
CENTRAL AFRICAN REP
SOUTH SUDAN
ETHIOPIA
KENYA
UGANDA
RWANDA
BURUNDI
TANZANIA
GABON
REP OF THE CONGO
CONGO
SAO TOME AND PRINCIPE
EQUATORIAL GUINEA
ANGOLA
ZAMBIA
NAMIBIA

The location of the island of São Tomé. Photo courtesy hyotographics/ www.shutterstock.com



One of two distinct species of caecilians on the island of São Tomé. Photo Andrew Standbridge © 2021.

A millipede as big as a car!

▲ A reconstruction of an *Arthropleura* millipede.
Photo courtesy FABRIZIO CONTE/www.shutterstock.com

A previously unknown species of gigantic millipede, which was the size of a car, has been unearthed in northern England! The fossil — the remains of a creature called *Arthropleura* — dates from the Carboniferous Period, about 326 million years ago, and over 100 million years before the Age of Dinosaurs. The fossil reveals that *Arthropleura* was the largest-known invertebrate animal of all time, larger than the ancient sea scorpions that were the previous record holders.

Discovered in the north of England

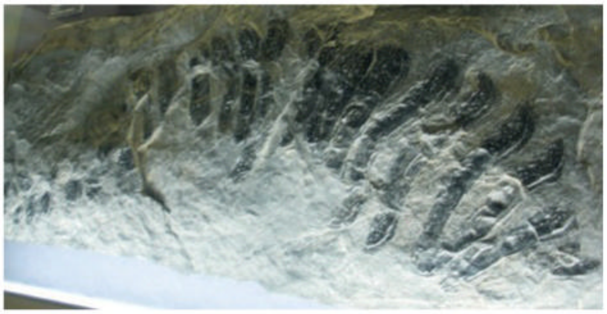
The specimen, found on a Northumberland beach about 65km (40ml) north of Newcastle-upon-Tyne, is made up of multiple articulated exoskeleton segments, broadly similar in form to modern millipedes. It is just the third such fossil ever found. It is also the oldest and largest: the segment is about 75cm (29.5in) long, while the original creature is estimated to have measured around 2.7m (8.9ft) long and weighed around 50kg (110lb).

The fossil was found in a large block of sandstone that had fallen from a cliff to the beach at Howick Bay in Northumberland. "It was a complete fluke of a discovery," admits Dr Neil Davies from Cambridge's Department of Earth Sciences. "Thanks to the way that the boulder had fallen, it had firstly cracked open and perfectly exposed the fossil, which one of our former doctoral students then happened to spot while walking by!"

Unlike the cool and wet weather associated with the region today, Northumberland had a more tropical climate in the Carboniferous Period, when Great Britain lay nearer the Equator. Invertebrates and early amphibians lived in association with scattered vegetation around a series of creeks and rivers. The specimen identified by the researchers was found in a fossilised river channel: it was likely a moulted segment of an *Arthropleura's* exoskeleton that filled with sand, preserving it for hundreds of millions of years.

The fossil was extracted with permission from Natural England and the landowners, the Howick Estate. "It was an incredibly exciting find, but the fossil is so large it took four of us to carry it up the cliff face," says Davies.

▼ The fossil was discovered on a beach at Howick Bay, Northumberland.
Photo courtesy Dave Head/www.shutterstock.com



One of the smaller German specimens, from the Senckenberg Museum of Frankfurt. Photo courtesy Ghedoghedo/ CC BY-SA 3.0

A good diet with plentiful availability of food is thought to have helped *Arthropleura* millipedes grow to a large size. Photo courtesy Ralf Jurgen Kraft/www.shutterstock.com

Other related finds

The millipede's remains were then brought south to Cambridge so that it could be examined in detail. It was compared with all previous records and revealed new information about the animal's habitat and evolution. This invertebrate clearly only existed in places that were once located at the Equator, such as Great Britain during the Carboniferous. Previous reconstructions have suggested that the animal lived in coal swamps, but this specimen revealed that *Arthropleura* preferred open woodland habitats near the coast.

There are only two other known *Arthropleura* fossils, both from Germany, and both much smaller than the new specimen. Although this is the largest *Arthropleura* fossil skeleton ever found, there is still much to learn about these creatures. "Finding these giant millipede fossils is rare, because once they died, their bodies tend to disarticulate, so it's likely that the fossil is a moulted carapace that the animal shed as it grew," explains Davies. "We have not yet found a fossilised head, so it's difficult to know everything about them."

New insight

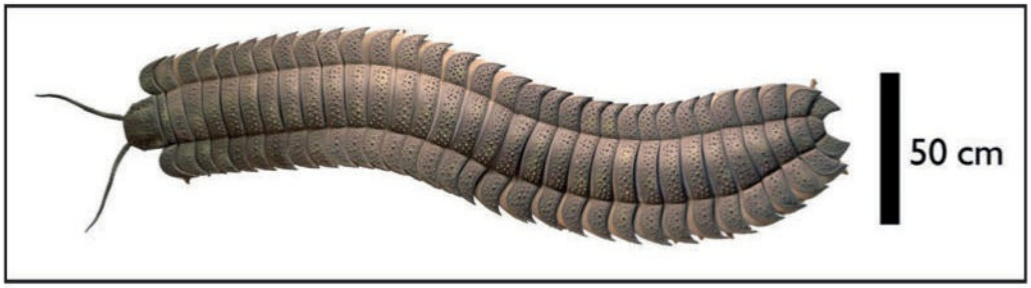
The great size of *Arthropleura* has previously been attributed to a peak in atmospheric oxygen during the late Carboniferous and Permian periods, but because the new fossil comes from rocks deposited before this peak, it shows that oxygen levels cannot be the only explanation.

The researchers therefore believe that to get to such a large size, *Arthropleura* must have had a high-nutrient diet.

"While we can't know for sure what they ate, there were plenty of nutritious nuts and seeds available in the leaf litter at the time, and they may even have been predators that fed off other invertebrates and even small vertebrates such as amphibians," said Davies.

What triggered their demise?

Arthropleura millipedes crawled around Earth's equatorial region for around 45 million years, before going extinct during the Permian period. The cause of their demise is uncertain, but it could be due to global warming that made the climate too dry for them to survive then, or to the rise of reptiles, who out-competed them for food and soon dominated the same habitats. If you are keen to see the newly discovered fossil, this will be going on public display at Cambridge's Sedgwick Museum during 2022.



A reconstruction of the new species. Photo courtesy J. W. Schneider. TU Bergakadamie Freiberg.

Further information

Neil S. Davies, Russell J. Garwood, William J. McMahon, Joerg W. Schneider, Anthony P. Shillito. **The largest arthropod in Earth history: insights from newly discovered *Arthropleura* remains (Serpukhovian Stainmore Formation, Northumberland, England).** *Journal of the Geological Society,* 2021; jgs2021-115 DOI: 10.1144/jgs2021-115

Snakes benefited from the mass dinosaur extinction

Modern snakes evolved from ancestors that lived alongside the dinosaurs and almost certainly fed mainly on insects and lizards. Then a large asteroid estimated to be about 10km (6.2ml) in diameter wiped out nearly all the dinosaurs and roughly three-quarters of the planet's plant and animal species 66 million years ago. This in turn triggered the spectacular diversification of mammals and birds that followed in the early Cenozoic Era.

A new University of Michigan (U-M) study shows that early snakes capitalised on that ecological opportunity and the smorgasbord that it presented, rapidly and repeatedly evolving novel dietary adaptations and prey preferences.

The study combines genetic evidence with ecological information extracted from preserved museum specimens.

➤ A green vine snake (*Oxybelis fulgidus*) in Brazil. This mildly venomous species is known to eat frogs, lizards, and birds.
Photo courtesy Ivan Prates, University of Michigan Museum of Zoology.

Winners, not losers

"We found a major burst of snake dietary diversification after the dinosaur extinction. Species were clearly evolving quickly and rapidly by acquiring the ability to eat new types of prey," explains scientist Michael Grundler.

Mammals and birds, which were also diversifying in the wake of this mass extinction event, began to appear in snake diets at that time. Specialised diets also emerged, such as snakes that feed only on slugs or snails, or snakes that feed exclusively on lizard eggs. Similar outbursts of dietary diversification were also seen when snakes arrived in new places, as when they colonised the New World.

"What this suggests is that snakes are taking advantage of opportunities in ecosystems," explains U-M evolutionary biologist Daniel Rabosky, who worked with Grundler. "Sometimes those opportunities are created by extinctions and sometimes they are caused by an ancient snake dispersing to a new land mass."

A blunt-headed tree snake (*Imantodes inornatus*) eating its way through a batch of treefrog eggs. Food of this type may have been a popular early food of snakes.
Photo courtesy John David Curlis, University of Michigan Museum of Zoology.

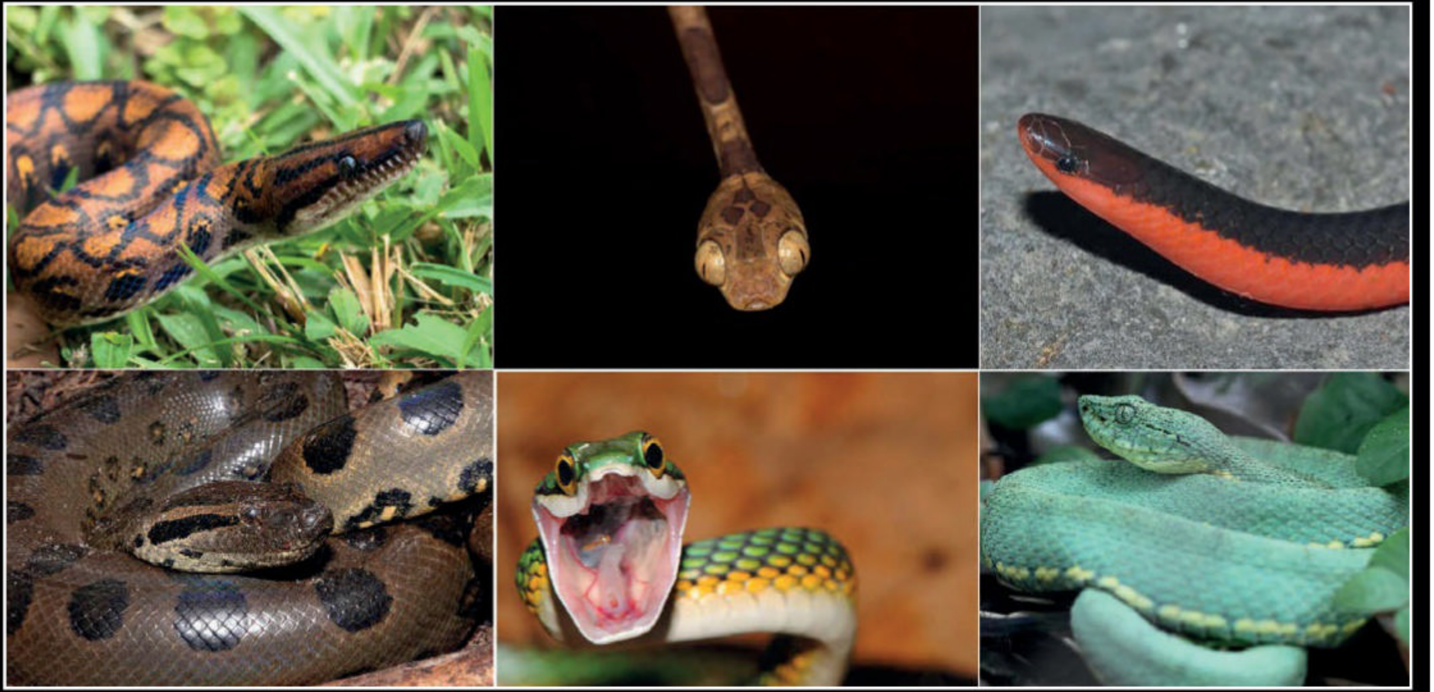
Growing diversity

Those repeated transformational shifts in dietary ecology were important drivers of what evolutionary biologists call adaptive radiation: the development of a variety of new forms adapted for different habitats and ways of life, according to Grundler and Rabosky.

Modern snakes are impressively diverse, with more than 3,700 species worldwide. And they display a stunning variety of diets, from tiny leaf-litter snakes that feed only on invertebrates such as ants and earthworms to giant constrictors like boas and pythons that prey on mammals as big as antelope.

Assembling a massive database

So, how did legless reptiles that can't chew come to be such important predators on land and sea? In order to



A sampling of snake diversity. Clockwise from upper left: rainbow boa (*Epicrates cenchria*), photo credit Pascal Title, U-M Museum of Zoology; Amazon basin tree snake (*Imantodes lentiferus*), photo credit Pascal Title, U-M Museum of Zoology; western worm snake (*Carphophis vermis*), photo credit Alison Rabosky, U-M Museum of Zoology; two-striped forest pit viper (*Bothrops bilineatus*), photo credit Dan Rabosky, U-M Museum of Zoology; parrot snake (*Leptophis ahaetulla*), photo credit Ivan Prates, U-M Museum of Zoology; and green anaconda (*Eunectes murinus*), photo credit Dan Rabosky, U-M Museum of Zoology.

These species range from generalist predators on vertebrates (rainbow boa and anaconda) to those that specialise in hunting sleeping lizards (tree snake), earthworms (worm snake), and tree frogs (parrot snake).

find out, Grundler and Rabosky first assembled a dataset on the diets of 882 modern-day snake species. This information includes more than 34,000 direct observations of snake diets, from published accounts of scientists' encounters with snakes in the field and from the analysis of the stomach contents of preserved museum specimens. Many of those specimens came from the U-M Museum of Zoology, which is home to the world's second-largest collection of reptiles and amphibians.

All species living today are descended from other species that lived in the past. But because snake fossils are rare, direct observation of the ancient ancestors of modern snakes — and the evolutionary relationships among them — is mostly hidden from view. However, those relationships are preserved in the DNA of living snakes. Biologists can extract that genetic information and use it to construct family trees, which they call phylogenies.

Looking directly into the past

Grundler and Rabosky merged their dietary dataset with previously published snake phylogenetic data in a new mathematical model that allowed them to infer what long-extinct snake species were like. "You might think it would be impossible to know things about species that lived long ago and for which we have no fossil information," says Rabosky, an associate professor in the U-M Department of Ecology and Evolutionary Biology and an associate curator at the Museum of Zoology.

"But provided that we have information about evolutionary relationships and data about species that are now living, we can use these sophisticated models to estimate what their original ancestors were like long ago."

In addition to showing a major burst of snake dietary diversification following the demise of the dinosaurs in what's known as the K-Pg mass extinction, the new study revealed similar explosive dietary shifts when groups of snakes colonised new locations.

▼ A keeled slug-eating snake (*Pareas carinatus*) on the prowl for prey in its southeast Asian homeland.
Photo courtesy Tukkatar/ www.shutterstock.com

Impact of new habitats

For example, some of the fastest rates of dietary change — including an increase of roughly 200% for one subfamily — occurred when the Colubroidea superfamily of snakes made it to the New World. The colubroids account for most of the world's current snake diversity, with representatives found on every continent except Antarctica. They include all venomous snakes and most other familiar snakes; the group does not include boas, pythons and several obscure snakes such as blind snakes and pipe snakes.

Grundler and Rabosky also found a tremendous amount of variability in how fast snakes develop new dietary tastes. Some groups, such as blind snakes, evolved more slowly and maintained similar diets — mostly ants and termite larvae — for tens of millions of years.

At the other extreme are the dipsadine snakes, a large subfamily of colubroid snakes that includes more than 700 species. Since arriving in the New World roughly 20 million years ago, they have experienced a sustained burst of dietary diversification, according to this new study.

The American pipe snake (*Anilius scytale*) is harmless but is frequently mistaken for dangerously venomous coral snakes. This colubrid species is a specialised predator of elongated vertebrates, including other snakes, as well as legless lizards and amphibians (caecilians).
Photo courtesy Dan Rabosky, University of Michigan Museum of Zoology.

Dietary diversity is remarkable today

The dipsadines include goo-eaters, false water cobras, forest flame snakes and hognose snakes. Many of them imitate deadly coral snakes to ward off predators and are known locally as false coral snakes. "In a relatively short period of time, species evolve to specialise in feeding on earthworms, on fishes, on frogs, on slugs, on snake-like eels — even other snakes," Grundler says.

"A lot of the stories of evolutionary success that make it into the textbooks — such as Darwin's famous finches — are nowhere near as impressive as those associated with some groups of snakes. The dipsadines of South and Central America have just exploded in all aspects of their diversity, and yet they are almost completely unknown outside the community of snake biologists."

Cat-eyed snake (*Leptodeira semiannulata*) in the Peruvian Amazon. This group of snakes have large, bulging eyes, with their pupils narrowing to vertical streaks, like that those of a cat. Their range extends from southern parts of Texas southwards to Peru, and they will feed on amphibians and their eggs, as well as small reptiles.
Photo courtesy Dan Rabosky, University of Michigan Museum of Zoology.

An emerald tree boa (*Corallus batesii*) in the Amazonian rainforest, with this species being a specialised predator of small mammals.
Photo courtesy Dan Rabosky, University of Michigan Museum of Zoology.

A unique resource

Rabosky and Grundler stressed that their study could not have been done without the information gleaned from preserved museum specimens. "Some people think that zoology collections are just warehouses for dead animals, but that stereotype is completely inaccurate," Rabosky says. "Our results highlight what a tremendous, world-class resource these collections are for answering questions that are almost impossible to answer otherwise."

Further information

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